MIT'S MAGAZINE OF INNOVATION

TECHNOLOGY REVIEW

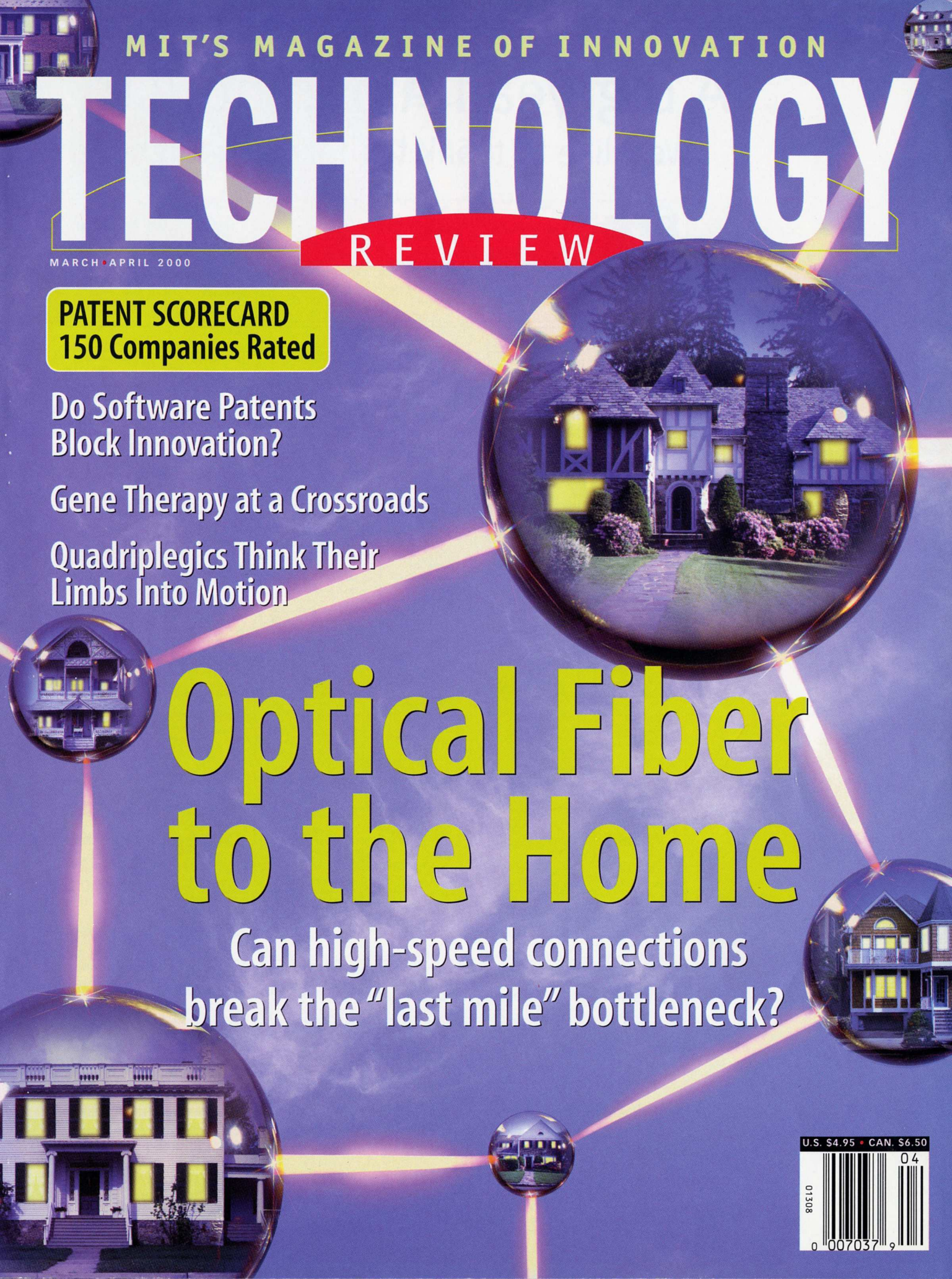
MARCH•APRIL 2000

PATENT SCORECARD
150 Companies Rated

Do Software Patents Block Innovation?

Gene Therapy at a Crossroads

Quadriplegics Think Their Limbs Into Motion



Optical Fiber to the Home

Can high-speed connections break the "last mile" bottleneck?

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technology
review
Published by MIT

A big year. A big industry.

We'd like to thank the following high-tech

RF Micro Devices, Inc.
$159,000,000
Follow-on Offering
January 21, 1999

Allaire Corp.
$57,500,000
Initial Public Offering
January 22, 1999

MicroVision Corp.
$42,200,000
Has Been Acquired By Electro Scientific Industries, Inc.
February 1, 1999

Veeco Instruments, Inc.
$213,800,000
Follow-on Offering
February 3, 1999

Exodus Communications, Inc.
$20,000,000
Has Acquired American Information Systems, Inc.
February 9, 1999

Maxtor Corp.
$143,000,000
Follow-on Offering
$162,500,000
Dividend Enhanced Convertible Offering
February 9, 1999

TranSwitch Corp.
$72,300,000
Follow-on Offering
February 9, 1999

GetSmart.com
$33,000,000
Has Been Acquired By Providian Financial
February 18, 1999

Enable Semiconductor, Inc.
$50,000,000
The Ethernet LAN Business of Enable Semiconductor, Inc. Has Been Acquired By Lucent Technologies, Inc.
March 2, 1999

DuPont Photomasks, Inc.
$83,500,000
Follow-on Offering
March 10, 1999

Infosys Technologies, Ltd.
$70,400,000
Initial Public Offering
March 10, 1999

Genesis Microchip, Inc.
$133,300,000
Has Acquired Paradise Electronics, Inc.
March 28, 1999

MKS Instruments, Inc.
$96,300,000
Initial Public Offering
March 29, 1999

NetGravity, Inc.
$147,800,000
Follow-on Offering
March 30, 1999

PassGo Technologies, Inc.
$50,000,000
Has Been Acquired By AXENT Technology, Inc.
March 31, 1999

PLX Technology, Inc.
$34,200,000
Initial Public Offering
April 5, 1999

MEMC Electronic Materials, Inc.
$200,000,000
Rights Offering & Private Placement
April 19, 1999

Sanmina Corp.
$300,000,000
Convertible Offering
April 29, 1999

Silknet Software, Inc.
$45,000,000
Initial Public Offering
May 5, 1999

RAScom, Inc.
$24,000,000
Has Been Acquired By Excel Switching Corp.
May 11, 1999

theglobe.com, Inc.
$120,000,000
Follow-on Offering
May 19, 1999

Optical Coating Laboratory, Inc.
$112,700,000
Follow-on Offering
May 21, 1999

Softline Consulting & Integration, Inc.
Not Disclosed
Has Been Acquired By KPMG LLP
May 25, 1999

Telescan, Inc.
$50,000,000
Has Acquired INVESTools, Inc.
June 1, 1999

Amdocs Ltd.
$490,000,000
Follow-on Offering
June 7, 1999

Numetrix Ltd.
$85,600,000
Has Been Acquired By J. D. Edwards & Company Banc of America Securities Acted As Financial Advisor To Numetrix
June 16, 1999

Streamline.com, Inc.
$50,800,000
Initial Public Offering
June 17, 1999

Dealer Solutions, Inc.
Not Disclosed
Has Been Acquired By ADP Dealer Services Group
June 25, 1999

Project Software & Development, Inc.
$14,500,000
Project Software & Development, Inc. Has Sold A Minority Interest To W. W. Grainger, Inc.
June 25, 1999

Manufacturing Technology Inc.
Not Disclosed
Has Been Recapitalized By TA Associates
June 30, 1999

TriQuint Semiconductor, Inc.
$193,900,000
Follow-on Offering
July 13, 1999

CORE Technology Group
Not Disclosed
Has Been Acquired By FutureNext Consulting
July 16, 1999

Webhire, Inc.
$20,000,000
40% of Webhire, Inc. Has Been Acquired By SOFTBANK Capital Partners
July 20, 1999

JDS Uniphase Corp.
$940,900,000
Follow-on Offering
July 27, 1999

Solectron Corp.
$1,092,300,000
Follow-on Offering
July 28, 1999

Internet Capital Group, Inc.
$255,800,000
Initial Public Offering
August 4, 1999

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companies for a record year.

Verity, Inc.
$86,100,000
Follow-on Offering
August 5, 1999

InterVoice, Inc.
$168,600,000
Has Acquired
Brite Voice Systems, Inc.
August 13, 1999

Ancor Communications, Inc.
$69,100,000
Follow-on Offering
August 19, 1999

eShare Technologies, Inc.
$54,500,000
Has Been Acquired By
Melita International
September 1, 1999

GET Manufacturing, Inc.
$243,000,000
Has Been Acquired By
Jabil Circuit, Inc.
September 13, 1999

Siebel Systems, Inc.
$300,000,000
144A Convertible
Subordinated Notes
September 21, 1999

uBid, Inc.
$52,000,000
Follow-on Offering
September 23, 1999

Digital Insight Corp.
$60,400,000
Initial Public Offering
September 30, 1999

Williams Communications Group
$762,500,000
Initial Public Offering
September 30, 1999

Williams Communications Group
$2,000,000,000
Senior Notes
September 30, 1999

Amdocs Ltd.
$502,000,000
Follow-on Offering
October 6, 1999

E-Stamp Corp.
$136,850,000
Initial Public Offering
October 8, 1999

Research in Motion Ltd.
$172,000,000
Follow-on Offering
October 13, 1999

PC-Tel, Inc.
$89,900,000
Initial Public Offering
October 18, 1999

Flextronics International Ltd.
$467,000,000
Follow-on Offering
October 25, 1999

BroadVision, Inc.
$223,600,000
Follow-on Offering
November 2, 1999

Advanced Energy Industries, Inc.
$135,000,000
Convertible Subordinated
Notes
November 4, 1999

Celestica, Inc.
$473,201,000
Follow-on Offering
November 9, 1999

Veeco Instruments, Inc.
$38,900,000
Has Acquired
Ion Tech, Inc.
November 9, 1999

Phone.com, Inc.
$1,024,700,000
Follow-on Offering
November 16, 1999

Metricom, Inc.
$600,000,000
Vulcan Ventures & MCI
WorldCom Have Invested
In Metricom, Inc.
November 16, 1999

Metron Technology, Inc.
$56,100,000
Initial Public Offering
November 18, 1999

Metalink Ltd.
$55,200,000
Initial Public Offering
December 1, 1999

Cerprobe Corp.
$36,000,000
Has Acquired
OZ Technologies, Inc.
December 3, 1999

NetRatings, Inc.
$78,200,000
Initial Public Offering
December 7, 1999

Kulicke & Soffa Industries Inc.
$175,000,000
144A Convertible
Subordinated Notes
December 8, 1999

eCollege.com
$60,500,000
Initial Public Offering
December 14, 1999

Cree Research, Inc.
$243,500,000
Follow-on Offering
January 13, 2000

RADWARE Ltd.
$129,400,000
Follow-on Offering
January 24, 2000

Corning, Inc.
$2,000,000,000
Follow-on Offering
January 25, 2000

Autobytel.com, Inc.
$31,800,000
Has Agreed To Acquire
A.I.N. Corp. d/b/a
CarSmart.com
Pending

JDS Uniphase Corp.
$2,800,000,000
Has Agreed To Acquire
Optical Coating
Laboratory, Inc.
Pending

JDS Uniphase Corp.
$15,200,000,000
Has Agreed To Acquire
E-TEK Dynamics, Inc.
Pending

Photronics, Inc.
$144,000,000
Has Agreed To
Acquire Align-Rite
International, Inc.
Pending

Signio, Inc.
$733,300,000
Has Agreed To Be Acquired
By VeriSign, Inc.
Pending

TREEV, Inc.
$104,000,000
Has Agreed To Be Acquired
By CE Computer
Equipment AG
Pending

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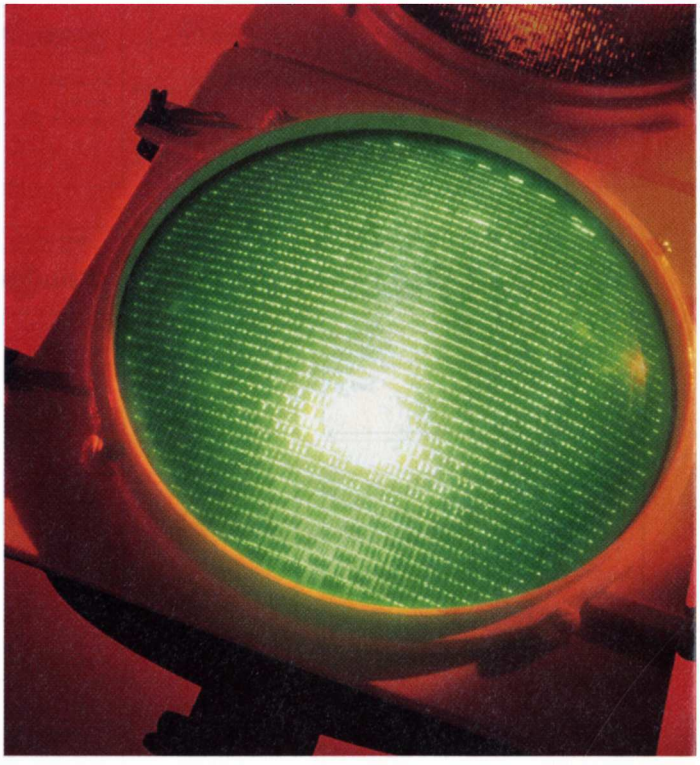

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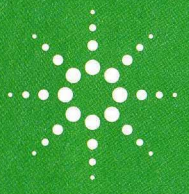

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VOLUME 103, NO.2

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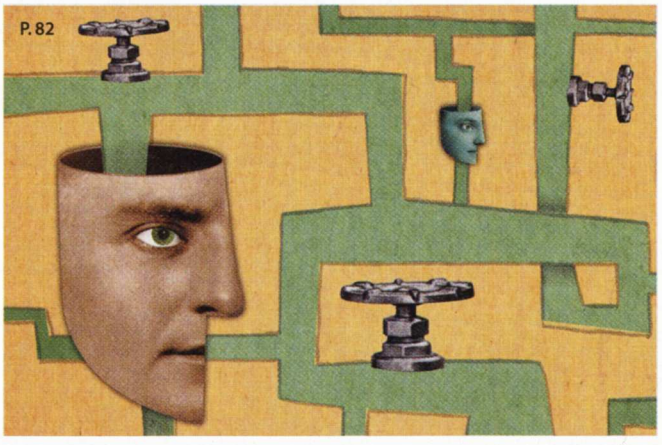

Cover illustration by James Porto

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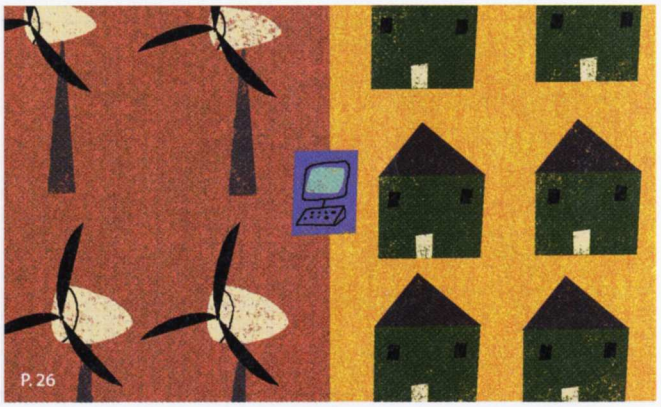

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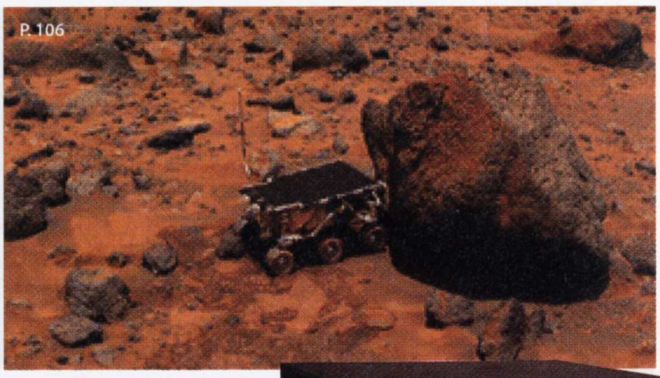

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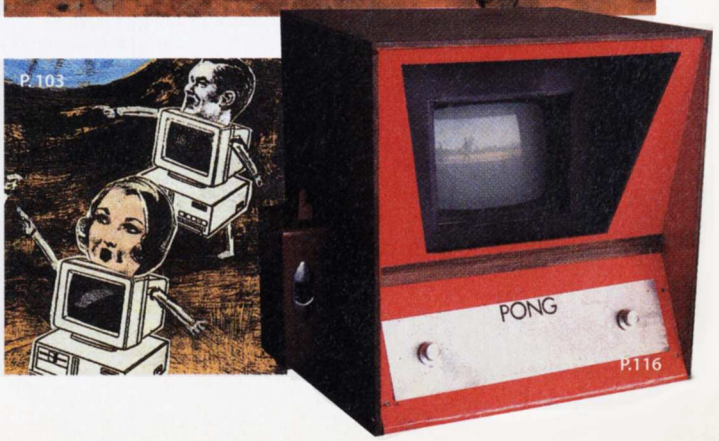

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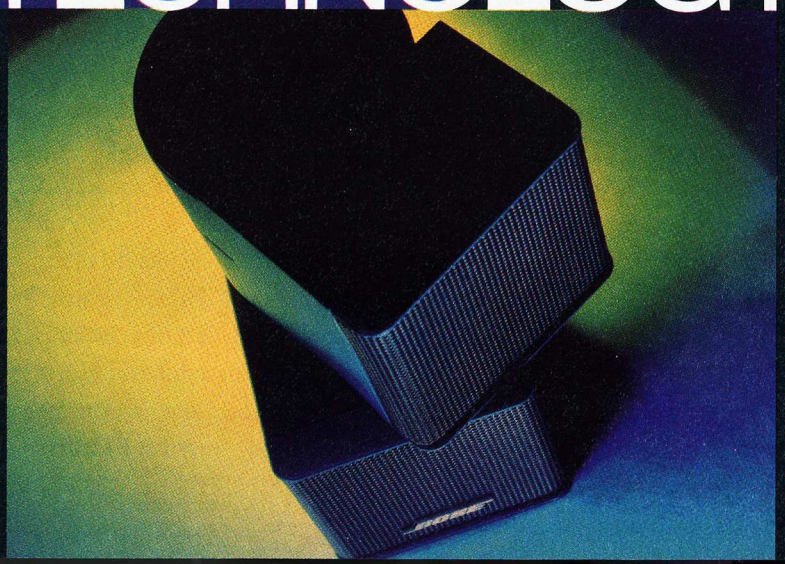
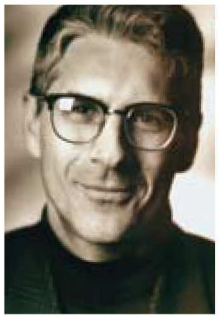


PRODUCTS SHOWN APPROXIMATELY 1/2 SIZE

Intellectual Capital

IN THE TWO YEARS WE'VE PUBLISHED THE NEW TECHNOLOGY REVIEW, WE'VE offered you a number of editorial packages on subjects we thought were worthy of more than just one article: nanotechnology, for example, and human-machine symbiosis. But none of the packages we've published in the past is as important, in my view, as this issue's Special Section on intellectual property.

Two trends are converging to make intellectual property—or IP, as insiders call it—particularly salient now. The first is that cheaper and more effective manufacturing, aided by computers and robotics, is driving down the cost of making material goods. The ultimate effect of this tendency is to make materials a less important component of finished products. The second trend is the changing nature of the corporation, triggered partly by the Internet. As companies outsource more of their operations and manage relations with their affiliates electronically, the essence of the firm shrinks to a central core. Prominent in that core is the company's intellectual property, including its treasured brand and all the assets that support the brand: patents, trademarks, traditions.



It takes a while for major trends like these to work their way through the economy, and there's a lot of inertia behind the old way of doing things. But the advent of the Web has pushed these twin developments forward with a vengeance. The day of intellectual property is here, and anyone who wants to surf the New Economy better understand what that means.

Here's what we think it means:

■ Starting now, corporations will spend much more time developing, managing and focusing their portfolio of intellectual property assets, including patents and brands. The first "Technology Review Patent Scorecard"(p. 58) shows which companies are the best at doing that. As Robert Buderi notes in the accompanying article (p. 82), companies are taking very different approaches to getting the most out of their intellectual property. But, whatever their specific approach, technology leaders are spending increasing time and energy on IP.

■ Web businesses will try to obtain patents that are as broad as possible on business methods—even methods that might seem too obvious to be patentable. In a provocative article (p. 68), Seth Shulman argues that the trend toward obvious and broad e-commerce patents reveals problems in the Patent Office that could roadblock innovation.

■ Companies will be more aggressive in protecting their brands and the assets that go with their brands. In his "Viewpoint" (p. 103), professor Henry Jenkins of MIT says that if media conglomerates prevent us from exchanging our own stories about media characters, they will reduce us to passive spectators in our own culture.

As the articles in our Special Section show, the growing significance of intellectual property has both benefits and drawbacks. But whatever the balance of good and evil, these developments aren't going away. Indeed, they will only become more marked in the future. Welcome to the world of intellectual capital. In recognition of this new environment, *Technology Review* introduces in this issue a new column called just that: Intellectual Capital (p. 79). The column will appear in every issue, written by a different expert in the field each time. By bringing you this range of voices, we will help you navigate the new world of intangible assets that's rising up in our midst. **—John Benditt**

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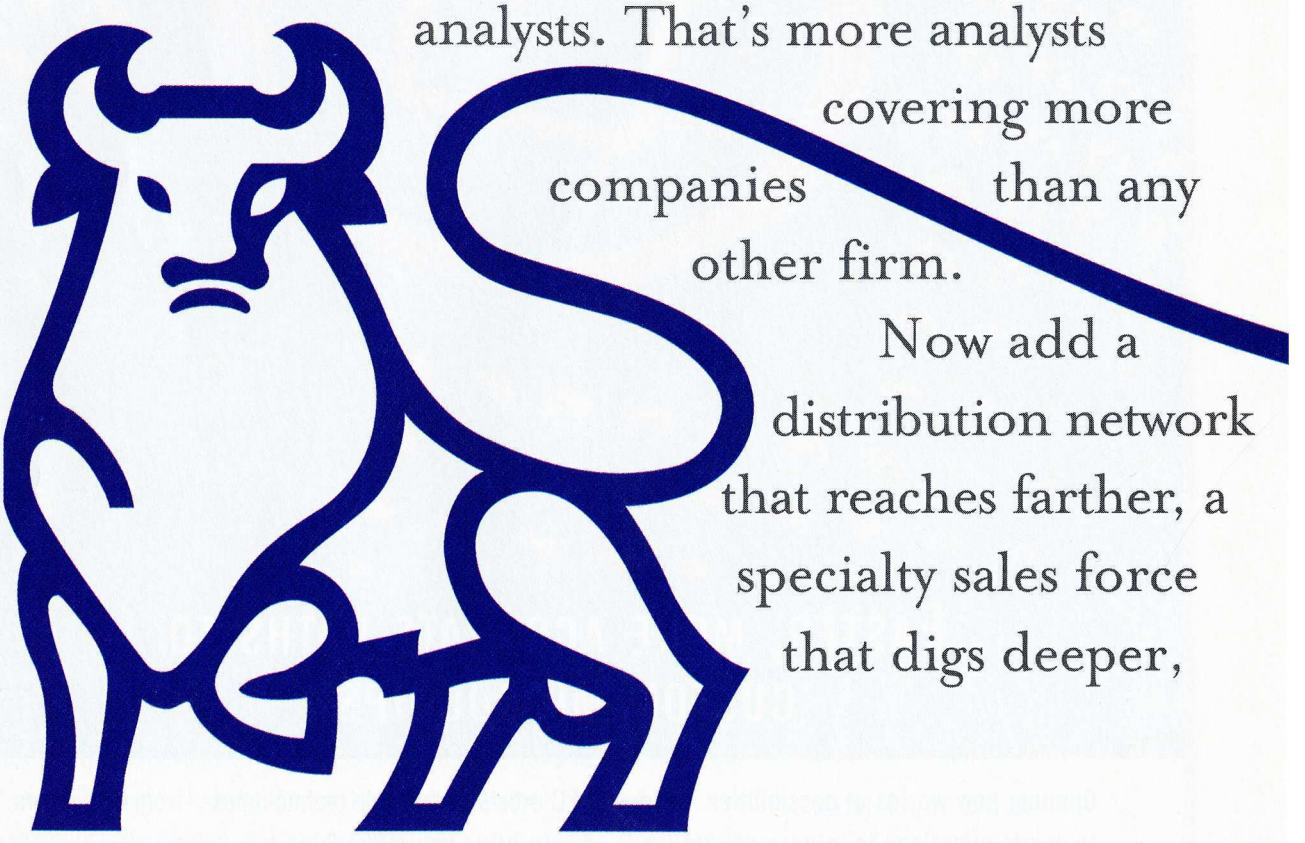

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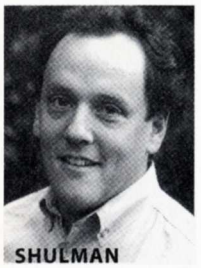
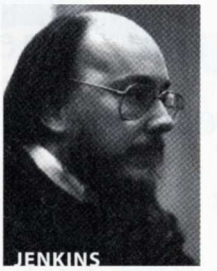
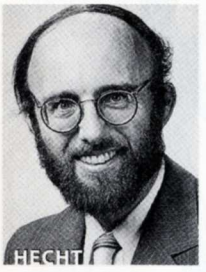
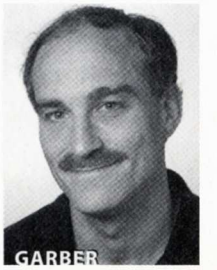
U.S. Patent and Trademark Office Commissioner Q. Todd Dickinson likes to joke that **Seth Shulman** kidnapped him last March. In fact, Shulman, a freelance writer who's been critical of the Patent Office, was simply giving Dickinson a ride to the airport after taping a radio debate when they ran into one of Boston's infamous traffic jams. Stranded together, the pair had a wide-ranging conversation in which Shulman learned about the sharp increase in and potential impact of a new breed of patents covering e-commerce. In his article "Software Patents Tangle the Web," on p. 68, Shulman argues the dangers of broad ownership claims on high-tech knowledge, a theme he also explores in his recent book *Owning The Future* (Houghton Mifflin, 1999). | Intellectual property rights also pose worries for Internet fan sites devoted to favorite comic books, movies and television stars. With online homages to "Buffy the Vampire Slayer" and "Star Trek" on the rise, media conglomerates such as Disney and Time Warner are increasingly taking on the role of killjoy, shutting down these enthusiastic tributes to their trademarked characters. In this issue's Viewpoint, **Henry Jenkins,** director of the Program in Comparative Media Studies at MIT, explores this threat to the Web's unique culture of fandom. Jenkins says Hollywood is searching for a compromise, but that the media giants can't "talk about a more active, participatory environment and culture for fans without letting people participate. Something has to give." | *TR* readers, however, can participate in the debate about intellectual property in the age of the World Wide Web—just tune into the online discussion that's happening at www.techreview.com/forums. Both Shulman and Jenkins will be right in the thick of the conversation, but the behind-the-scenes task of maintaining the forums falls to *TR* Webmaster **Jeff Foust,** an MIT PhD with a passion for planetary science. Foust recently published *The Astronomer's Computer Companion* (No Starch Press, 1999), a guide for amateur astronomers who want to use the Internet to discover the stars. While studying the heavens, Foust keeps his feet firmly planted on the ground with his homage to New England minor and major league baseball at www.baseballguide.com. | Patents, copyrights and trademarks aren't the only things that will determine the growth of e-commerce and fan clubs in cyberspace. Another factor is bandwidth, and in "Fiber Optics to the Home," p. 48, freelancer **Jeff Hecht** reports on the prospect of lightning-quick Internet, phone and network connections for every American household. Hecht discovered that while fiber-optic cable is being installed sporadically in the United States, most people still live on the Internet's equivalent of a dirt road. Hecht, a resident of the Auburndale section of Newton, Mass., has resigned himself to watching the phone company "go up and down my street, fixing their crummy phone lines." | On p. 58, first-time *TR* contributor **Ken Garber** explores a different sort of revolution in "High Stakes for Gene Therapy," a story that sketches the hopes and worries of researchers who are at the forefront of the search for one of medicine's most elusive goals: a genetic cure for hemophilia. Garber is a self-taught science journalist and avid rock climber who says scientists he meets on the rocks near his home in Michigan are some of his best sources. TR


SHULMAN


JENKINS


HECHT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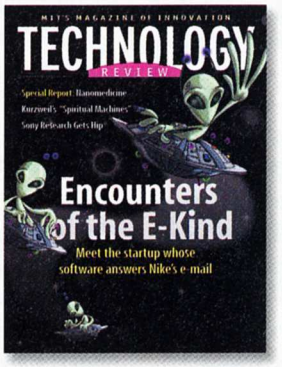
"Waldrop captured the essence of J.C.R. Licklider and my own recollections of him —from his kindness to his vision."

Lick Letters

J.C.R. LICKLIDER MAY BE "ALMOST FORgotten", but not by me ("Computing's Johnny Appleseed," *TR* January/February 2000). As an undergraduate, I heard a lecture by a dynamic young teacher whose name reminded me of Art Linkletter. He told a vignette about trying to get neophyte Army Air Force pilots to remember to put their wheels down before landing. The solution was to take the knob off the landing gear lever and replace it with a tiny black rubber tire with treads and all. I've used that story time and again to illustrate the need for human understanding and understanding humans in the development of technology. Thank you J.C.R.L. and forgive me for committing a common sin of youth, not recognizing when one is in the presence of genius.



CARL F.W. WOLF
Professor of Clinical Pathology
New York-Presbyterian Hospital
New York, NY

WALDROP CAPTURED THE ESSENCE OF LICK and my own recollections of him—from his kindness to his vision. My first interaction with Lick was as an engineer at Digital Equipment Corp. building the first timesharing system for Bolt Beranek and Newman. Thanks for reconnecting me with a wonderful old friend.

GORDON BELL
Senior Researcher
Microsoft
San Francisco, CA

I BARELY KNEW LICK, BUT I HAVE ALWAYS had tremendous admiration for his vision. With so many vying to be recognized as "father of the Internet" it is a shame that Lick isn't universally accorded that title.

ALEX MCKENZIE
Rockport, MA

LICKLIDER'S STORY GIVES US A WINDOW (no pun intended) into the process by which a technology becomes, as networked computing did in this case, a defining characteristic of our age. The present dot-com culture depends on lots of hardware and software, but none of that would have mattered without a vision of what the technology was to accomplish. His story further illustrates how having such vision, though critical, is not enough. One also needs the willpower, and in Lick's case, access to funding, to push that vision onto a sometimes-skeptical community.

PAUL E. CERUZZI
Washington, DC

Upload Us?

RAY KURZWEIL'S VIEW OF TECHNOLOGY and the future of "man" seems part of an emerging consensus on the man-machine relationship ("The Story of the 21st Century," *TR* January/February 2000). Stephen Hawking, in a talk at the White House last year, envisioned a race between biology and cyber technology—as humans gain control of their evolutionary processes to keep up with the increasingly competent machines they invent.

These are well argued views of the future, but one wonders if the pace of technology doesn't race ahead, outstripping the adaptive abilities of humanity, resulting in social fragmentation as scattered clusters of disparate advanced technologies take root in separate receptive communities around the planet. Vast gaps between classes of people would emerge, not just in income and wealth, but in the very experience of what it means to be alive.

Kurzweil's body of work—using technology to enhance the lives of those physically impaired—exemplifies an important commitment that will be required of the future scientific and technical leadership: a view of science and technology that reaches out across boundaries for the greater public good.

BOB ALEXANDER
President
Alexander and Associates
New York, NY

ANYBODY CAN MAKE BIZARRE PREDICTIONS about the future, but it takes a Ray Kurzweil to make them sound convincing too.

MAHESH SHANTARAM
Technology Journalist
Bangalore, India

KURZWEIL MAY BE BRILLIANT BUT HE IS wrong. The fact that the brain is in a constant state of structural change—dendrites growing, new neural and chemical pathways, biochemical environments changing—implies that the brain scanned one nanosecond will be entirely different the next nanosecond. In fact, from the time the first area of the brain is scanned until the next area is scanned both areas will have changed—even the scanning and scanner themselves will cause change.

JOE KONN
Berkeley, CA

I AM GLAD THAT I AM OLD ENOUGH TO BE near to saying goodbye to my "squishy body" in 30 years, the time frame in which Kurzweil sees us being able to self-replicate via nanotechnology. I believe that his predictions will become reality, and this scares me to death. I see a world where the bioengineered robots are the superior "beings" and human beings, with our inferior minds, are nothing more than worker bees. We must be a simple race if we can envision this outcome and continue on our path of self-destruction.

REBECCA O'SULLIVAN
Newmarket, Ontario

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Please include your address, telephone number and e-mail address.
Letters may be edited for clarity and length.

Michael's Mojo

TR'S JANUARY 2000 ISSUE IS A SIGHT TO behold. First, Michael Dertouzos sings "Kumbaya" for us ("The Enlightenment

Bug," *TR* January/February 2000). His assessment that the Enlightenment somehow disturbed the holistic unity of human relations is absurd. The Enlightenment broke the centuries of ignorance and tyranny that resulted from mixing faith and legitimate power. Perhaps he should read up on the history of Copernicus and Galileo to see why the Enlightenment was necessary before dismissing it for messing with his mojo. Secondly, G. Pascal Zachary fights the conjecture and hype of nanotechnology with...conjecture and hype. Lastly, Eamonn Fingleton takes us back to the nineteenth century with a ringing endorsement for tariffs. What next—angels on the cover?

Brad Clawsie
Menlo Park, CA

Thank you for exposing so eloquently the role technology's immense growth is having on our development as whole people with spiritual, technological and humanistic qualities and needs. Technology does not erase the larger fundamental questions of life and death, and should not be relied upon by society to play this part. Striving to teach our children and inform our daily activities with a perspective that encompasses both technology and spiritualism will help us take the best of what we've got going in the technology world and combine it with what distinguishes us from machines: humanity, in all its wonder, hope, fear and courage.

Joanna Gerson
Editor, Top of the Net
Retail Systems Alert Group
Newton Upper Falls, MA

AI is OK

I was disappointed to see G. Pascal Zachary displaying such ignorance of the current state of in artificial intelligence ("Nano-Hype," *TR* January/February 2000). He wrote: "Remember artificial intelligence? Computers were going to automatically translate from one language to the next. Take dictation. Run factories without human intervention. Lead space missions." Yet machine translation of technical documents has been an active commercial business for years; there are even Web sites that will translate Web pages on demand. There are also at least three major vendors of PC-based voice-dictation software. As for industrial applications of AI, I refer Zachary to any recent proceedings of the Innovative Applications of Artificial Intelligence Conference, which every year describes industrial automation using artificial intelligence. Finally, although AI systems do not yet lead space missions, the most recent NASA deep-space probes use AI autonomous reasoning techniques to compensate for the long communication delays back to Earth. Speaking as an MIT-educated artificial intelligence researcher since the 1970s, let me say that it is hard enough doing the work required to make progress in a difficult field without gratuitous jabs like Mr. Zachary's.

Charles Rich
Newton, MA

Truth in Manufacturing

Since I share many of Eamonn Fingleton's concerns about the U.S. manufacturing base ("The Unmaking of Americans," *TR* January/February 2000), I was disappointed to see his argument collapse under the weight of its inaccuracies and half-truths. For starters, the semiconductor manufacturing industry's largest power

by far is U.S.-based Intel. The list of U.S.-based manufacturers is quite long, and also includes such household names and global powers as IBM, Motorola and Texas Instruments. Though many (but not all) of these companies do use steppers from non-U.S. vendors, Fingleton conveniently failed to mention that the world's largest semiconductor manufacturing equipment supplier, Applied Materials, is based in the U.S. So are KLA-Tencor and Kulicke & Soffa—which hold dominant positions in the process metrology and chip assembly equipment segments, respectively—and too many other major suppliers to mention here. It is true that both semiconductor-grade silicon production and LCD manufacturing are concentrated outside the U.S. But 56 percent of world sales of glass substrates for LCDs go to Corning, a long-standing titan of U.S. industrial production. Perhaps a discussion of the lessons the semiconductor industry can teach other U.S. manufacturers would have been more useful than yet another descent into knee-jerk protectionism.

KATHERINE DERBYSHIRE
Managing Editor
Semiconductor Online
Stoneham, MA

Fingleton responds: *Derbyshire implies that I said that American manufacturing has disappeared, but my point was that it's a shadow of its former self. I don't dispute that the corporations she mentions have a continuing presence. I would simply point out that they, like most American high-tech manufacturing firms, are dependent on Japan for key materials, components and production machines. Take Intel. The company does much of its manufacturing outside the United States, so it is a less important contributor to the U.S. job base and trade position than its revenues might suggest. Secondly, Intel is dependent on Japanese inputs and machines. Thirdly, it owes its standing in the semiconductor industry not to superior manufacturing skills but to its lucky position as half-owner of the Wintel standard.*

At the end of the day, what matters is trade—Derbyshire fails to mention the United States' $6-billion-a-month trade deficit with Japan. Despite Intel, the United States is a huge net importer of chips. That people as informed as Derbyshire should sweep this under the carpet is precisely why I believe a review of the United States' position in high-tech manufacturing is vital.

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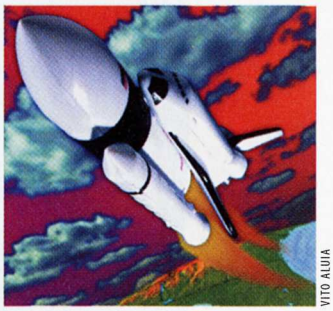
WEB W/O

Boron vs. Cancer

Biomedical researchers would like to be able to deliver chemicals directly to a cell nucleus—cancer therapy being one reason. UCLA chemist Fred Hawthorne may have discovered a chemical "roach motel" that provides entry to but no exit from the nucleus. He found the passageway while trying to get boron-rich compounds into cells in studies of a cancer treatment called boron neutron capture therapy (BNCT). In BNCT, boron atoms interact with neutron beams to create an unstable isotope that blows apart, as if the neutron had tripped a landmine inside the cell.

Hawthorne has designed novel, small molecules called nido-carboranyl oligomeric phosphate diesters—nido-OPDs—that carry boron into cell interiors more effectively than before. Although Hawthorne expected that the small nido-OPDs molecules would diffuse in and out of the nucleus, he found that they accumulated; once the molecules checked in, they didn't check out. Most were still present in the nucleus 24 hours later, a finding that could help make BNCT a much more effective cancer treatment in the future.



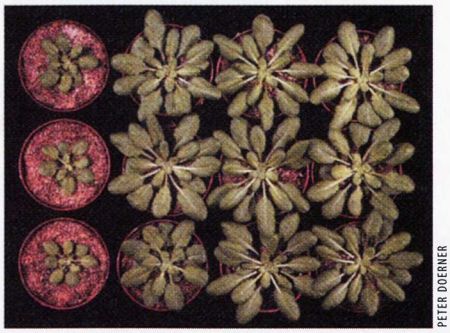
VITO ALUIA

Mission: De-mining

Removing land mines has always been tough. Now it's rocket science. Engineers at Thiokol Propulsion, in cooperation with NASA's Marshall Space Flight Center, have developed a flare that uses surplus rocket fuel to disable mines safely. The flare is placed next to an uncovered mine and detonated from a distance. The flare burns through the mine's casing and consumes the explosives within it, disabling it or minimizing the force of its detonation. The flare is much less hazardous than current techniques, such as deactivating the mine by hand or deliberately detonating it. Each flare uses about 100 grams of surplus propellant intended for the space shuttle's solid rocket boosters that could otherwise not be reused. An initial batch of 700 flares was made late last year, according to Thiokol program manager Carol Campbell; those flares are being tested in Kosovo and Jordan.

Gene Thumb

Grow! That's Nature's prime directive to living things, and one that genetic engineers have harnessed for making powerful drugs such as human growth hormone. This time, University of Edinburgh scientist Peter Doerner has used genetic engineering to create plants that just plain grow faster and bigger—up to three times as big, in fact.



PETER DOERNER

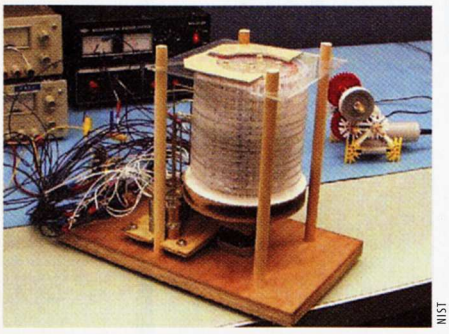
Precocious plants (right) have an extra gene.

In 1996, Doerner discovered that a gene called cyc-1 helps control the rate at which plant cells divide. Now he has created a strain of *Arabidopsis thaliana*, a flowering mustard plant, with an extra copy of this gene that kicks in at just the right moment in the cell-division process. The payoff will come in crops like rice, which could reach maturity faster with the new gene inserted, enabling farmers to squeeze in an extra harvest.

Fingers Do the Reading

Computers are just as important to people who are blind as they are to the rest of us. But current systems of translating screen displays into the raised dot letters of the Braille alphabet are pretty clumsy: They require nearly 500 moving parts called actuators to display entire pages at a time. Now comes a device, invented by John Roberts and colleagues at the National Institute of Standards and Technology (NIST) in Gaithersburg, Md., that uses as few as three moving parts.

A stream of Braille letters formed along the edge of a rotating wheel is the basis for the new display. Each turn of the wheel presents a new line of Braille text. Fingers held just above the rotating wheel read the dots as they go by. A commercial Braille wheel using this design could be about the size of a portable CD player and much cheaper than current displays. Software has been written for the wheel to display scrolling text from electronic books.



NIST

Scrolling Braille, simply.

Date Data

You suddenly realize you have a meeting in 15 minutes with a company you faintly remember encountering a few months ago at a trade show. You're scheduled to brief your boss prior to the meeting—but realize you have no idea what the company actually does. An "active" electronic calendar being developed at IBM Almaden Research Center in San Jose, Calif., could be just the thing to rescue you.

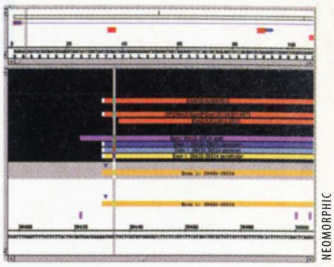
The calendar automatically collects relevant information on its entries. It can, say, gather links to notes from previous meetings, Web pages displaying the company's financials, new-product information—even technical papers written by the visitor. For offsite activities, the calendar serves up maps, directions and lists of nearby hotels—and alerts you that a convention on your favorite hobby will be in progress a block away. IBM scientists have the calendar up and running but decline to say when it will be commercialized.

An Ear to the Web

"The decline of america is dual to the automatic transmission home which actually came way back and go for the peace made a sleazy made us lazy." Modern poetry? Actually, it's a transcript of National Public Radio's popular "Car Talk" program generated by SpeechBot, an experimental engine for interpreting and searching audio content on the Web created at Compaq's Cambridge Research Laboratory (www.compaq.com/speechbot).

SpeechBot downloads audio files from the Internet, then uses speech-to-text software to make a transcript, says Compaq researcher Pedro Moreno. Although the software is specially tuned to decipher typical Internet file types like RealAudio, variable quality and a large number of different speakers keep accuracy low—the Car Talk guys' thick Boston accents and tendency to talk over one another may make recognition tougher than usual. Even in this example, though, enough keywords came through to make the search worthwhile.

The Visible Gene



NEOMORPHIC

Zoom in, zoom out, scroll and annotate. Work on genetic maps, or DNA sequences, or raw data from automated sequencers. Combine different widgets or resize windows and dynamic data structures keep details in sync. That's what you can do with software that a Berkeley, Calif., startup called Neomorphic has developed for visualizing the floods of genetic information pouring out of the Human Genome Project.

Neomorphic's software is coded as Java applets and launched through Web browsers. Linked to gene datasets online, the applets deliver micro and macro perspectives on particular groups of genes. University of California at Berkeley researchers have used the software since November to describe more than 13,000 fruit-fly genes—one every 15 minutes. Lead bioinformaticist Suzanna Lewis takes confidence knowing human eyes have gone over the data, and adds: "It's awesome to see the genes come cranking out."

Glare Guard

Blinding glare is a common—and sometimes dangerous—problem for drivers, welders, commercial pilots, even for optical sensors in delicate equipment. Now a Penn State researcher has made liquid crystal materials that perform a kind of optical jujitsu—reacting to the light intensity by increasing their own opacity and blocking out the glare.

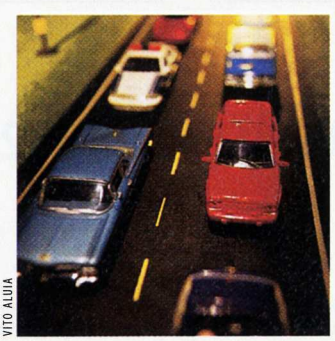
I.C. KHOO

Liquid crystals block a spot of bright light (right).

Electrical engineering professor I.C. Khoo says the most promising initial applications are protective goggles for anyone exposed to bright light or lasers, such as commercial pilots or welders. In addition, says Khoo, devices based on the materials could protect sensitive optical detectors used in instruments and satellites. He expects to build prototypes by this summer but declines to elaborate on what they will be used for. Research funding comes from the U.S. Army and the Naval Air Development Center.

Traffic Hot Spots

Future weathercasters might add a traffic temperature to their forecasts. Georgia Tech civil engineer John Leonard is developing a traffic model of Atlanta that incorporates historical data and other variables, ranging from day of the week to special events and weather conditions, to estimate traffic conditions for the coming day. To make it simpler to interpret the model's output, Leonard distills the results into a single congestion index, or "temperature." Leonard's model incorporates data from a network of video cameras and other detectors that monitor the city's freeways; a byproduct is a real-time contour map of travel times from selected points. Over time, Leonard says, the model will adjust itself to reflect the way that people alter their driving patterns in response to the computer predictions. Full implementation of the model, which could be used elsewhere, remains several years away.



VITO ALUIA

Mouse to House

Online shopping—with the ability to track your package in real time—is a great convenience. But even the Web can't solve the pesky problem of delivery: Often as not, nobody's home in the middle of the day. That's the problem that Arlington, Va., startup Mental Physics is tackling. This spring, the company will pilot test a secure, electronically networked home delivery bin that closes the Internet ordering loop. A delivery person punches in a code that unlocks the bin and simultaneously transmits a signal through a pager network. When the resident arrives home, she enters her own retrieval code to unlock the bin again; the message that the package has been retrieved goes out through the pager to a Mental Physics office, which relays this information to the merchant. The smart bins should also make it easier to return products. Put the rejected item in the bin and hit a button, and the box will signal Mental Physics to send a truck to the house. Mental Physics has partnered with renowned design firm IDEO (whose credits include the Palm V) to create an attractive and functional bin.

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extreme networks **$136,850,000** Initial Public Offering	extreme networks **$575,575,000** Follow-On Offering	f5 **$34,500,000** Initial Public Offering	f5 **$169,510,000** Follow-On Offering	GlobeSpan Accelerating Communications **$56,062,000** Initial Public Offering
NEWBRIDGE Newbridge Networks Inc. **$234,800,000** *has acquired* TIMESTEP & NORTHCHURCH	PACKETEER **$69,000,000** Initial Public Offering	PARADYNE **$117,300,000** Initial Public Offering	PARADYNE **$155,620,000** Follow-On Offering	ramp NETWORKS **$50,600,000** Initial Public Offering

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Private Placement	Initial Public Offering	Follow-On Offering	Initial Public Offering	Follow-On Offering
Juniper NETWORKS	Juniper NETWORKS	mck	NETCORE SYSTEMS, INC.	Netro
$187,680,000	**$1,092,500,000**	**$62,560,000**	**$20,500,000**	**$46,000,000**
Initial Public Offering	Follow-On Offering	Initial Public Offering	Private Placement	Initial Public Offering
Redback NETWORKS Access. Power. Innovation.	TORRENT Networking Technologies Corporation	TRANSWITCH	VERTICAL NETWORKS	VIXEL
$66,125,000	**$450,000,000**	**$72,335,000**	**$30,000,000**	**$89,010,000**
Initial Public Offering	*has been acquired by* ERICSSON	Follow-On Offering	Private Placement	Initial Public Offering

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E-mail: Freedom or Jail?

IF YOU ARE A NEWCOMER TO THE INTERNET, ONE of your first proud pleasures is the exchange of e-mail. If you are an old hand, you are probably lamenting the daily assault on your time, and are scrambling to reduce it. New or old, you are headed for a tenfold increase in received messages during the coming decade, as the number of interconnected people grows and as each person and organization increases their use of e-mail. You are also headed toward new capabilities—maybe at the extreme, skydiving in your goggles and body suit and e-mailing the experience to your friend, who will play it back through her e-mail apparel! But exciting as future improvements may be, they will be dwarfed by a present, real and growing overload.

Every piece of e-mail you get demands attention, be it a second to trash it, or 15 minutes to compose a reply. A normal person needs an average of two to three minutes to process a message. If you only get one or two messages a day, you have no reason to worry, even under a tenfold increase. And you probably treasure the ability to communicate with others. For many people who are alone, or live far away from loved ones, e-mail is a godsend.

Are you ready to send and receive ten times as much e-mail as you do today? Probably not. We all need to adopt e-mail survival strategies: birth control and euthanasia.

But if you spend 45 minutes a day handling e-mail today, the coming increase will require eight hours of your daily attention, leaving no time for any other work. This may still be appropriate if all you do is message handling. But if, like most people, you treat e-mail as auxiliary to your main work, you can't let it exceed 10 percent to 20 percent of your time, in other words, an hour a day. If you are near this load level, as most people I know seem to be, your e-mail will explode past what you can tolerate.

What are you to do?

You can begin with a mixture of technological and human procedures. Stripped of fancy descriptions, this medicine amounts to two options: birth control at the source, and euthanasia at the destination!

Responsible e-mail behavior starts by avoiding the "look Ma" syndrome—sending messages and copies to show off, or to ensure that everyone remotely interested stays informed. Prolific e-mail authors should think of each message they send as an instrument that reduces the recipient's life by two to three minutes. They should send it only if they judge that the effect justifies the cost. This may sound unreasonably harsh, especially since all human work involves invasions into other people's time. But e-mail differs from face-to-face encounters where everyone's time is equally taxed. That's because with only a flick of a finger you can send copies to a huge number of people: If you take 15 minutes to compose a message and send it to 60 people—a common situation with preset mailing lists—you will be taxing the recipients by two to three hours, while taxing yourself by fifteen minutes.

Besides through thoughtfulness, e-mail birth control can be achieved with office procedures, like an easy-to-use and socially accepted method for getting your name permanently removed from mailing lists; or a prize for the worker who, in the eyes of fellow employees, exhibits the "best e-mail behavior."

More can be done at the destination: Filters, built into mail-handling programs, can let people designate what messages to throw out, or channel to other people automatically, based on sender's name, topic or other such information. Unsolicited e-mail may be placed in suspense mailboxes and reviewed at a later time, or not at all, or until and if a second request is received from the same sender. Requiring that all telemarketing e-mail be tagged, for example with the new metadata capabilities of the Web, would be another good way to control unsolicited messages, not only for blocking them but also for letting through the ones you want.

Even as it overloads us, e-mail helps us work better, receive the opinions and suggestions of our peers, and assess the pulse of our organization. To sustain these benefits while increasing my own productivity, I have constructed an array of electronic pushbuttons, using a program called Quick Keys. Each button inserts a preset message informing the recipient of my conclusion or question, forwards the annotated message to the designated party, and removes the mail from the incoming message queue—all with one click. As a result, my per-message average has dropped to about one minute. Measures like these can be helpful, but only for the short term.

For the long haul, we must go beyond all of the above tactics to understand and follow this basic principle:

Just because we have become electronically interconnected, we have not acquired the automatic right to send a message to anyone we wish, nor the automatic obligation to respond to every message we receive.

Ultimately, if e-mail overload becomes intolerable, "survival" will kick in and we'll trash everything in sight, as we should. After all, the principal role of information is not to be an end goal, but a means toward satisfying human needs and purposes. Let's keep it that way. ◊

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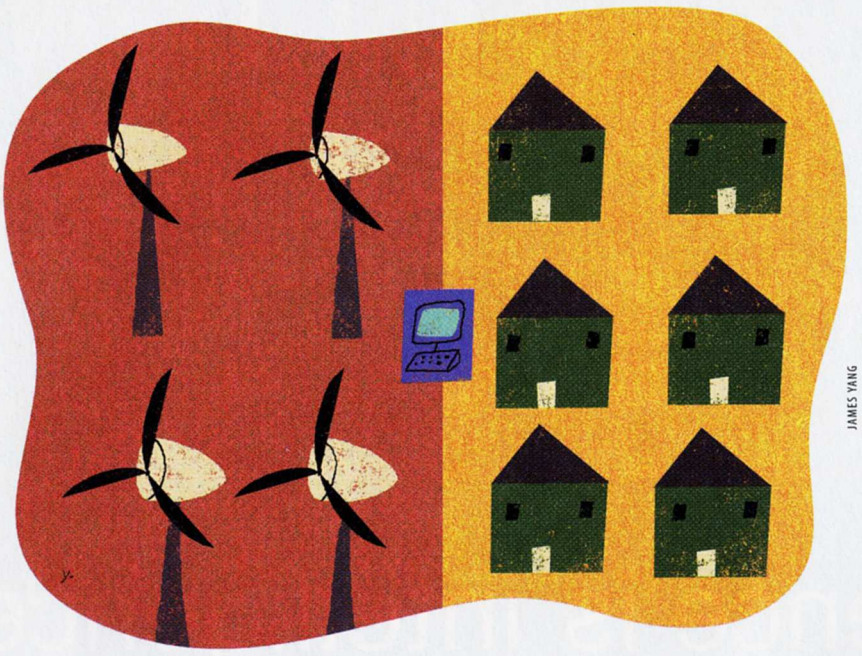


JAMES YANG

ENERGY

Power Picks

Now you can buy your electric power online

SOMETHING RADICAL IS HAPPENING in the staid world of electricity production. While most people give little thought to where their electricity comes from, the deregulation of the power industry now under way in a number of states means that, for the first time, consumers will have a choice of how the electricity that they pay for is produced. And in states that have already deregulated their electricity monopolies, consumers are increasingly choosing renewable energy sources, such as wind power, over cheaper but more highly polluting coal and other fossil fuels.

A startup called GreenMountain.com is the company moving most aggressively to take advantage of this "green" preference in what the U.S. Department of Energy estimates is a $217 billion electricity market. Indeed, by making the choice of renewable energy just a mouse click away, Vermont-based GreenMountain hopes to establish itself as the green brand of energy. "I want to be the Starbucks, the Coca-Cola, and the Ben & Jerry's of electricity all rolled up into one," says Dennis Kelly, GreenMountain's president and CEO.

More than half of the states have or are starting to dismantle their electricity monopolies. GreenMountain has already begun business in two—California (where 66 percent of electricity comes from coal, oil and nuclear power) and Pennsylvania (which generates 98 percent of its electricity from fossil fuels and nuclear power). This year, the company will enter Connecticut and New Jersey, with New York and Massachusetts not far behind, according to Kelly. So far, more than 100,000 households, plus businesses such as Kinko's and Birkenstock, have switched to GreenMountain.com, even though it costs a typical household between $6 and $12.50 more per month.

Customers sign up for the service on the company's Web site, then have their power delivered through the same municipal power grids and electrical lines they've always used. The difference is that GreenMountain.com offers an environmentally cleaner mix of energy than conventional power producers, who rely heavily on fossil fuels and nuclear power. The startup produces or buys all its energy from renewable sources, including windmill farms in three states. And it recently broke ground on a $10 million windmill farm in rural Pennsylvania that it says will produce enough electricity to power 2,500 homes.

But the business of green energy has not been all clean sailing. While the company claims that 100 percent of its energy comes from renewable sources, Kelly acknowledges that a large part of it is derived from older hydroelectric dams—facilities that can have a negative impact on fish and local wildlife. In addition, the company has had financial woes. After losing $65 million prior to an aborted attempt at an initial public offering in 1999, the company scaled back its plans to create a "green portal" for the Web. Currently, it is attempting to raise $100 million more in venture capital funding.

And the more customers GreenMountain signs up, the more big-time rivals it will attract. "If they are at all successful, they will encourage competitors, including the big utilities in the power-generating business to match their environmental performance," says Francis Cummings, a principal at Xenergy, a Burlington, Mass. consulting firm. "Now it's just a segment of the market. But as the availability of environmentally sustainable power becomes known, it could become the mainstream." **—Evan I. Schwartz**

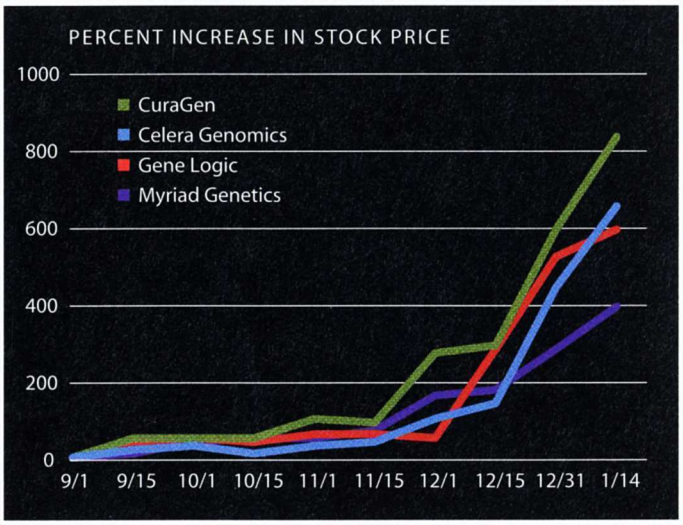
The GreenMountain.com site offers an environmentally cleaner mix of energy than conventional power producers.

MARKETS

Gene Stocks Take Off

DNA is Wall Street's latest craze

WHAT'S GOT NO PROFits and a sky-high stock price? If you said "the latest dot com," guess again. This time it's the dozen leading companies in genomics research. Since December, firms including Gaithersburg, Md.'s Gene Logic and New Haven's CuraGen have seen their stocks soar as investors tune into what scientists have known for a while—genome research is the future of medicine.



Driving the surging stock prices is the impending completion of the international Human Genome Project. In December, academic teams announced that they have decoded one of the 23 human chromosomes, with a rough draft of the rest of the genome to follow this year. And growing media coverage is drawing attention to companies that specialize in interpreting gene data to speed the search for new drugs—a field known as functional genomics *(see p. 94)*.

"Investors are looking for places to put their money where there is an opportunity to change the world," says Bill Hockett, director of investor relations for Salt Lake City's Myriad Genetics, whose stock has seen a 400 percent increase over the last four months. Hockett thinks another draw is that genomics companies offer a mix of information technology and biology, which appeals to investors who've seen big gains in Internet and software stocks. At Myriad, for instance, gene scientists rely heavily on technologies with an IT flavor such as bioinformatics and DNA chips.

But can these stocks continue to defy gravity as Internet ones have? Some Wall Street watchers don't think so. Jim McCamant, publisher of the *Medical Technology Stock Letter*, notes that many of these companies don't have clear plans to turn a profit and face complex intellectual property issues that investors don't appreciate. He points to Celera Genomics, the profitless 1998 startup that is racing to create a private copy of the human genetic code and whose market value has soared to $6 billion. "As a group," says McCamant, "I think these companies are overvalued."

—Antonio Regalado

SOFTWARE

Web Package Tours

Back when the Web was wilderness, it made sense that the main tool for pathfinding was a browser's "Back" button. Prudence dictated that you be able to retrace your steps, like Hansel and Gretel following a trail of bread crumbs. Now that the digital frontier resembles parkland more than wilderness, some Web wanderers are rethinking that navigational imperative.

Among them is entrepreneur Philip Copeland. While sailing off the coast of his native Australia, Copeland had an epiphany. He was using GPS technology to guide his way. And he recalls: "I wondered: Why can't the Web be this easy to navigate, with pointers leading you from one way-station to the next?" Copeland rounded up venture financing and started Spot On, in San Mateo, Calif. His mission: create a new way to move around the Net.

The Spot On recording tool lets users assemble a sequenced list of site addresses, along with annotations, to create a Web "tour" that can be shared with others who use the Spot On reader software. Basic versions of recorder and reader are free; Spot On will derive revenue by making enhanced versions available for a fee and by working with companies to create tours of their proprietary sites.

Because the tours are sequenced in advance, the browser software always knows what site the user will be visiting next. While the user is reading one page, the browser is fetching the next page into a memory cache. Clicking the "Next" button brings up the new site with minimal delay—a strong incentive for users not to jump off and claw their way alone through the cyber thickets.

It's a "really attractive tool," says network services director Darcy Fowkes of Aberdeen Research in Palo Alto, Calif. Fowkes sees Spot On as particularly useful for online publications that want to guide readers through their pages with less chance of them hopping off into the Web at large.

—Herb Brody

UNIVERSITY RESEARCH

Rough Sailing at the Media Lab

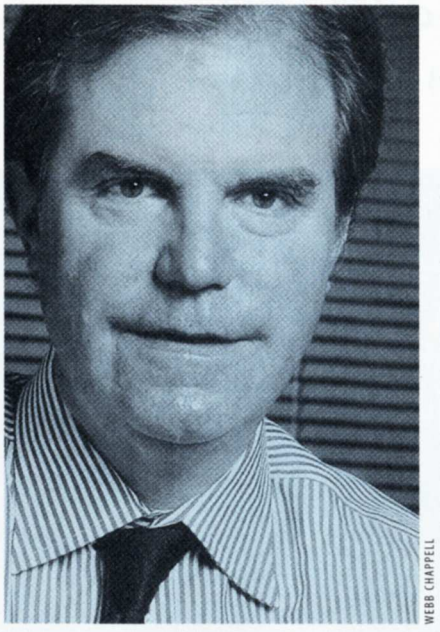
Can it adapt to the New Economy's love of intellectual property?

IT SHOULD HAVE BEEN A RESTFUL few days as the faculty of MIT's famous Media Lab arrived at the Maryland shore last July for their annual retreat. But the brainstorming and rejuvenation session—including meetings aboard a Chesapeake Bay sailing schooner—soon ran into turbulent waters. The issue: whether impending changes in the lab's intellectual property (IP) rules could destroy the facility's special character.

The financial realities of the new economy, it seems, are catching up with one of the world's eminent centers of digital research. Since its 1985 formation, the Media Lab has followed an unusual model: Corporations pay for a sponsorship (current requirements involve contributing at least $200,000 annually for three years or longer) and in return get free licensing rights to any technology developed. That arrangement has succeeded brilliantly in making the lab a model of academic-industrial collaboration (more than 90 percent of its $30 million budget comes from industry). But it has also meant that lab members can find it more difficult to profit from their own innovations than some MIT colleagues.

The problem goes beyond money to the core of the lab's educational mission and its ability to attract and retain top-flight talent. "What's happening is that the new economy is rewriting the rules of how people decide what to do with their lives, all the way back into how they go to college or whether they are going to be a professor," says Media Lab associate professor Ted Selker. Proactive institutions, he argues, must revisit their deals with faculty and students to match these societal changes, "because the consequences of not doing that is in fact no less than the loss of the best and the brightest people entering and staying at these institutions."

At MIT, as at many other universities, most researchers get one-third of the licensing royalties from their inventions. Things are different at the Media Lab, though, where staff members receive two-thirds of any royalties—if a non-



WEBB CHAPPELL

Negroponte is determined to balance the Media Lab's openness with greater IP protection.

sponsoring company licenses the technology. The hitch is that the lab's sponsors, among them many leading corporations, have free and open access to any lab inventions. It is this twist in IP policy that can make it difficult for lab staffers to turn a hot new technology into a royalty-earning success.

The Media Lab does have its share of startups: witness high-flying E Ink, a leader in developing electronic paper, which formed in 1997 with funding from some lab sponsors. Other Media Lab backers, though, frown on such ventures. Often, they're not as worried about missing out on key technology as they are about losing the chance to work with the very creative people who drew them to the lab in the first place.

It looks as though a movement is afoot to unsnarl this tangle. In January, lab director Nicholas Negroponte discussed the matter with MIT provost Robert Brown and dean of engineering Thomas Magnanti. While Negroponte declines to share the details of what he calls "a very constructive solution" that is in the works, he notes that the proposed changes "alter some of the basic tenets of MIT."

According to inside accounts, the various solutions under consideration have caused heated arguments—and hold the potential to polarize the facility. "Certainly, there are some people who have more of an inclination towards entrepreneurship outside of the lab, and others who are putting their entrepreneurial effort into the laboratory," says Walter Bender, who heads the News of the Future group. "I think that's a problem for all universities today."

Some fear that in their efforts to keep the best and brightest, the Media Lab could go too far to accommodate those with a more business-oriented bent, destroying its climate of intellectual openness. Notes one professor who requested anonymity: "There's concern that the changes in the outside world, the fact that there's potential for people to make such huge sums of money, might lead to more incentive for people to hide their ideas while they're here. I think that would be really harmful."

Negroponte seems intent on staking out a middle ground that allows greater IP protection while maintaining the lab's basic funding model and openness. Exactly what form that will take—and how fast change will come—remains to be seen. But the aim is to have everything set by the time the lab expands into a second building in 2003. Meanwhile, one place almost certain to reflect a different approach to intellectual property is the MediaLabEurope, an independent offshoot set to begin operations in Dublin this spring.

"Nicholas [Negroponte] said this really nicely," notes Bender. "One of the biggest problems that face universities today is that 20 years ago the entire effort of a university would be focused on things like starting Media Labs—while today it's focused on starting my.coms. And so the universities are suffering from that."

Bender adds, "We want to come up with structures that foster some kind of balance—and we're working toward that."

—Robert Buderi

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INTERNET

Protecting Your Privacy Online

One company offers a way for Internet users to keep their activities private

COURTESY OF ZERO KNOWLEDGE SYSTEMS

"ON THE INTERNET NO ONE KNOWS you're a dog," mused one canine to another in a famous 1993 *New Yorker* cartoon. Today, though, thanks to techniques ranging from Web browser "cookies" to sophisticated data mining, they may know you're a dog—and even which breed.

Companies can combine information voluntarily submitted by users with data automatically transmitted by a user's Web browsers and other software to provide a detailed picture of an individual. In some cases, interested parties can discover detailed personal information about people who visit their Web sites or use their software.

Montreal-based Zero Knowledge Systems (ZKS) believes it has the solution for people worried about online privacy. In December the company unveiled Freedom, a system that uses sophisticated encryption software and servers to cloak the true identity of an Internet user behind a pseudonym that no one other than the user—not even the company—knows. While there have been previous efforts to provide anonymous Web and e-mail access, they have been far less sophisticated than Freedom, according to analysts. "ZKS Freedom is the strongest and broadest privacy-enhancing technology I've seen," says Jason Catlett, a privacy advocate and president of Junkbusters, a company that helps consumers reduce the number of online and offline "junk" messages they receive.

A Freedom user downloads the client software (for Windows 95 or 98; MacOS and Linux versions are in the works) from www.freedom.net and installs it on his or her computer. An annual fee of $49.95 allows the user to register up to five separate identities, or "nyms," that identify the user while visiting Web sites, sending e-mail or performing any other Internet activity. Multiple layers of encryption, by both the client software and a series of servers used by Freedom to route traffic between the user's computer and the rest of the Internet, prevent anyone from intercepting the packets and connecting the nym with the user's real identity.

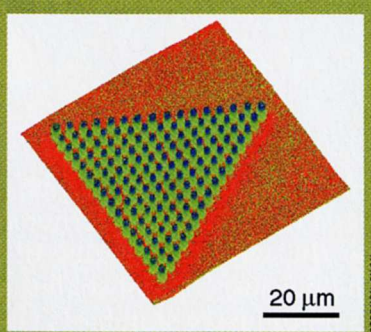
Some observers doubt that technology alone, as opposed to regulation, can solve the privacy issues on the Web. Austin Hill, president of ZKS, puts his faith in technology. "I'd prefer to have my privacy protected by strong encryption than by a promise from anyone," he says. However, he acknowledges, "technology can't solve everything, so there needs to be a mix."

—Jeff Foust

NANOTECH

Intelligent Self-Assembly

One dream of scientists making ultrasmall devices is coaxing materials to spontaneously form structures on a scale of micrometers, even nanometers. (A nanometer is one billionth of a meter.) The problem is how to control the location and orientation of structures made by this "self-assembly." Now a group of researchers at Princeton University may have stumbled across one solution: a way to form precise arrays of tiny pillars exactly where you want them. By providing a potentially cheap and easy method to make tiny structures, the technique could eventually lead to such things as even smaller integrated circuits and a simpler way to sort DNA molecules.



STEPHEN CHOU

A triangular array of plastic pillars, each half a micrometer in height and width.

Researchers in the lab of Stephen Chou, professor of electrical engineering, were working on a fabrication method using a mask to imprint nanometer-scale patterns on a polymer film. In a surprising result, they found that when microscopic particles of dust prevented the mask from contacting the polymer, micrometer-sized columns spontaneously formed in neat arrays under the protruding parts of the mask. Chou says he still doesn't know exactly why the pillars form. But he quickly realized it could be a much more controllable method to self-assemble tiny structures.

"The power of the method," says Chou, "is that it puts intelligence in self-assembly, and it could work for almost any [liquid] materials." Chou is working on ways to make organic light-emitting devices used in flat-panel displays in which each pixel consists of a cluster of tiny pillars—a result that would greatly improve the reliability and color reproduction of the displays. Chou also suspects that the ultrasmall pillars could be used to form interconnects in nanoscale electronic devices.

—David Rotman

Deutsche Banc Alex. Brown

What was behind Deutsche Bank's "Breakthrough Technology Deal of the Year"? Perfect timing.

FOUNDRY NETWORKS

$144 million
Initial Public Offering

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September 1999

Good timing paid off handsomely for Foundry Networks Inc. and Deutsche Banc Alex. Brown – awarded the "Breakthrough Technology Deal of the Year" by *Investment Dealers' Digest*.

By waiting until they were posting regular profits with a stable, world-renowned customer base – an unusual move in today's hot Internet IPO environment – Foundry achieved an astonishing 525% opening-day increase in share price.

Foundry has been working with Deutsche Banc Alex. Brown for over three years. Together, with Foundry's business model, we've crafted a strategic approach designed to make the very most of their market opportunity. And maximize the overall value of the company.

Time is a precious commodity. We successfully use it to maximum advantage – another reason why Deutsche Bank is leading to results.

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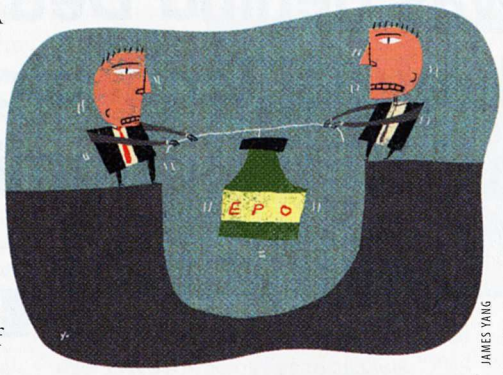
PHARMA

Blood Feud

Biotech's top-selling drug gets competition

IN BIOTECH, ONE DRUG CAN MAKE A company. For Amgen of Thousand Oaks, Calif., the nation's largest biotech firm, that drug is the anemia treatment erythropoietin (EPO). The best-selling protein racked up $1.75 billion in revenues for Amgen in 1999 and is paying for the 87,000-square-meter (285,000-square-foot), state-of-the-art laboratory the company is building in the heart of Cambridge, Mass.



JAMES YANG

But just a few blocks away, at Transkaryotic Therapies (TKT), some clever Cambridge competitors are set to challenge Amgen's pre-eminence with a version of EPO they believe gets around Amgen's suite of patents. If successful, TKT's "end-around" could lead to additional knockoffs of some of the world's largest-selling biotech pharmaceuticals.

In the early 1980s, Amgen was first to discover and patent the gene that encodes the EPO protein. To manufacture EPO, Amgen adds a copy of the gene to rodent cells growing in culture. TKT's strategy calls for using human cells instead; latent copies of the EPO gene are turned on in human cells grown in the lab, bypassing Amgen's patents on the gene and its production method.

Amgen originally hauled TKT into court in 1997. But TKT sidestepped the legal challenge thanks to a loophole that immunizes companies from patent infringement suits while testing a drug. Now that TKT and its partner, the French-based drug firm Aventis, have finished studies in patients and are preparing to seek FDA approval to market its version of EPO, the parties are set to meet Amgen in a Boston courtroom this April.

Robert Frank, an attorney with Boston's Choate, Hall & Stewart who represents TKT, says the case will be significant not only because of the money at stake, but also because it will test just how well-defended the patents that undergird biotech's pioneering companies really are. TKT is betting that it's found a chink in their armor. After EPO, TKT has secrecy-shrouded plans to take on six more of the top drugs in the worldwide $15 billion protein-therapy market.

—Antonio Regalado

AGBIOTECH

Healthier Frankenfoods?

When Swiss scientists reported earlier this year a genetically engineered strain of rice that produces beta-carotene, a source of vitamin A, it was hailed as a breakthrough that could help save the lives of an estimated 1 million to 2 million children each year in the developing world. It also came as a much-needed shot in the arm for the beleaguered agricultural biotech industry.

The growing opposition to biotech foods around the world is threatening the future of the technology. And a number of industry executives now acknowledge that the problem with first-generation products—for example, Monsanto's herbicide-resistant soybeans and insect-tolerant corn—is that while they may save farmers money and cut down on chemical use, they lack a visible payoff for the average shopper. "There may be risks with no benefit. So the consumer says 'why should I put up with it?'," says David Wheat, an industry analyst at the Bowditch Group in Boston, Mass.

While nutrition in developing countries has never topped the biotech industry's to-do list, companies hope their next generation of products gets a warmer reception. That generation will include many crops with genetically engineered "output traits" that improve a plant's taste, size or nutritional value. One of the first to reach market is a DuPont soybean engineered to produce a frying oil without trans-fatty acids, a current villain in public health circles. "The consumer won't know quite what kind of oil was used to make the donut, but the consumer can read a label that says zero trans-fats and that's what matters," says Wheat. According to Virginia Tech's Information Systems for Biotechnology, about 16 percent of the 800 biotech plants currently in field testing are aimed at improving such output traits.

—Antonio Regalado

On the Biotech Plate

ORGANIZATION	PRODUCT	STATUS
Agritope	Slow-ripening melons, tomatoes and raspberries	Field tests
DuPont	High oleic soybeans for healthier cooking oil	Marketed
Dow Chemical	Corn with increased starch levels	Field tests
Monsanto	Amino-acid enhanced corn for animal feed	R&D
Swiss Federal Inst. of Technology	Beta-carotene producing rice	R&D

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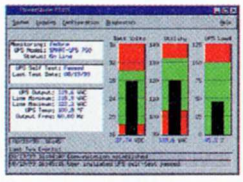

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Not Com

I'VE GOT A CONFESSION TO MAKE. I DON'T OWN any Internet stocks. Not one. Nada, zip, zero. Dot com, I ain't.

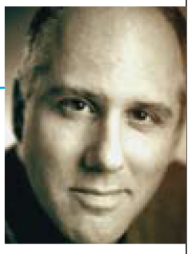
Call me old-fashioned, but my instinct is to discourage people from buying shares in companies that don't have profits or even products.

My confession helps explain why I find the humongous salary paid to a so-called "Queen of the Internet" obscene.

The "queen," in case you don't know, is one Mary Meeker, author of a book on Web businesses and holder of an MBA from Cornell University. Meeker, 40, was given her moniker by *Barron's,* the respected financial weekly. Her nickname caught on and has been broadcast by such elite publications as *The Wall Street Journal. Fortune* named her the third most influential woman in U.S. industry.

Meeker is a genuine technological visionary, or so her press agent, the media and scads of Web executives say. In this, she is an emblem for our times, a Gatsby of the Internet. Though she is forever opining about the future of technology, Meeker has never sold a line of code or published a scientific paper or founded a high-tech business. Yet last year she earned a reported $15 million from Morgan Stanley, the top-drawer Wall Street firm. Meeker's achievement: She touts Internet and e-commerce stocks.

Am I old-fashioned? It offends me that Mary Meeker, "Queen of the Internet," earned $15 million last year.



People who tout stocks are known as "analysts" in the industry, and in the pecking order of Wall Street they have traditionally rated a distant third in compensation behind stock traders and the investment bankers who actually raise money for companies. A scant half-decade ago, respected high-tech analysts earned $150,000 a year, 100 times less than Meeker's 1999 take.

The rise of Net stocks changed all this by elevating the status of stock analysts. Because the value of Net companies is based almost entirely on future performance (since many of them don't even have any revenues, let alone profits), analysts fill a crucial role in explaining to potential investors just how these new businesses will mature into market-dominant, profit-heavy titans. The best Net analysts combine the revolutionary zeal of Che Guevara with the cynicism of P.T. Barnum.

It helps to be positive. Some analysts routinely anger companies they cover by advising people to unload their shares. Not Mary Meeker. As of late last year, according to published reports, she'd never placed a "sell" order on any e-commerce stock in her decade as an analyst.

But, hey, don't underestimate the value of cheerleading. The rewards can be immense. Morgan Stanley, Meeker's employer, was the leader in bringing shares of Net companies to the public in 1999, ringing up as much as $100 million in fees from underwriting initial public offerings of Net stocks. Meeker gets a lot of credit for this from Morgan Stanley—and from the firm's competitors.

Meeker's success offends me. Call me jealous or mean-spirited, but I just can't accept it when *Barron's* insists Meeker is *underpaid.* Or maybe I just want an excuse to issue a reminder that when stock analysts earn more than inspired engineers and scientists, society loses. It isn't fair that innovators who don't happen to pursue e-commerce languish. Is it really possible that energy, materials, transportation and a variety of medical technologies aren't worth betting on, too?

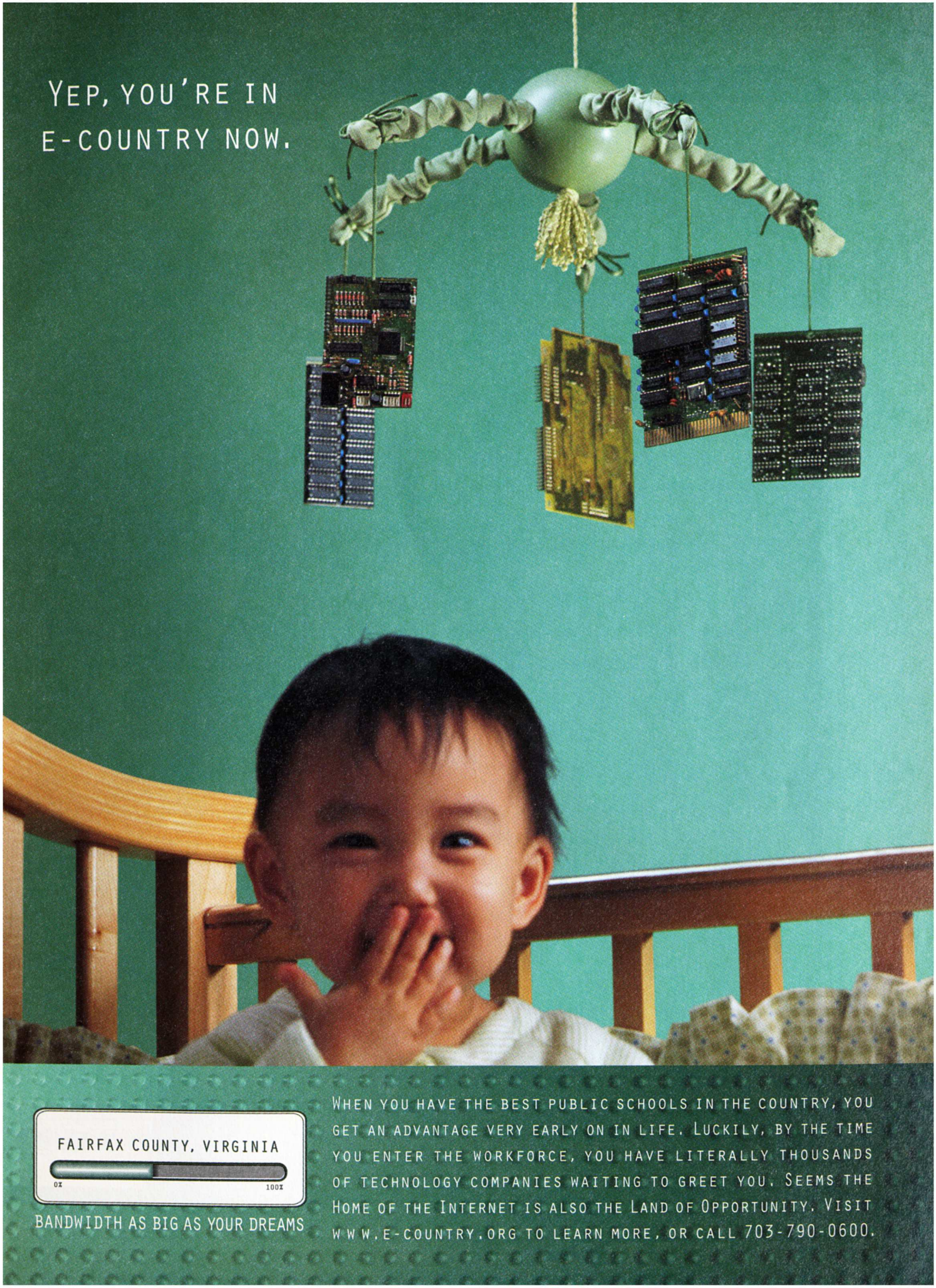
There's no way of telling what promising innovations in other fields are being ignored; it's impossible to know for sure everything that *hasn't happened* as a result of the Internet frenzy. But the numbers are sobering. In the final quarter of 1999, venture capitalists directed a whopping $5.2 billion into Internet-related startups, more than four times the amount one year before. Sadly, the decision to go hog-wild on the Net wasn't based on deep insights into the future of technology but the simple fact that the market value of Net stocks soared last year to $1 trillion, from $200 million.

Meeker is the human face behind one of the great sales jobs of modern times. When everyone—big or little—wants a piece of a Net stock, then there'd better be plenty to go around. Meeker helps to create the excitement around the companies entering the market, ensuring that there is enough to go around.

If there were justice in the world, Meeker would stick around as a Net analyst long enough to see if her grandiose predictions start to come true. Then even if her picks went south, she'd gain credibility by patiently explaining her failures. But in the surest sign that I'm not crazy after all, Meeker isn't likely to do this. She is quietly plotting her exit from her field, according to published reports.

Meeker won't comment on reports of her exit plans or any aspect of this column (she's too busy, her PR person says), but Meeker-watchers say she may soon join a high-tech business. Fittingly, in my opinion, she has her sights on a so-called "incubator" company whose aim is to launch other Net companies. The incubator Meeker is expected to join intends to sell stock to the public later this year.

No doubt Meeker is needed to help this incubator sell stock. But it makes you wonder. When companies go public who help other Net companies go public, it would seem the endgame is near. ◊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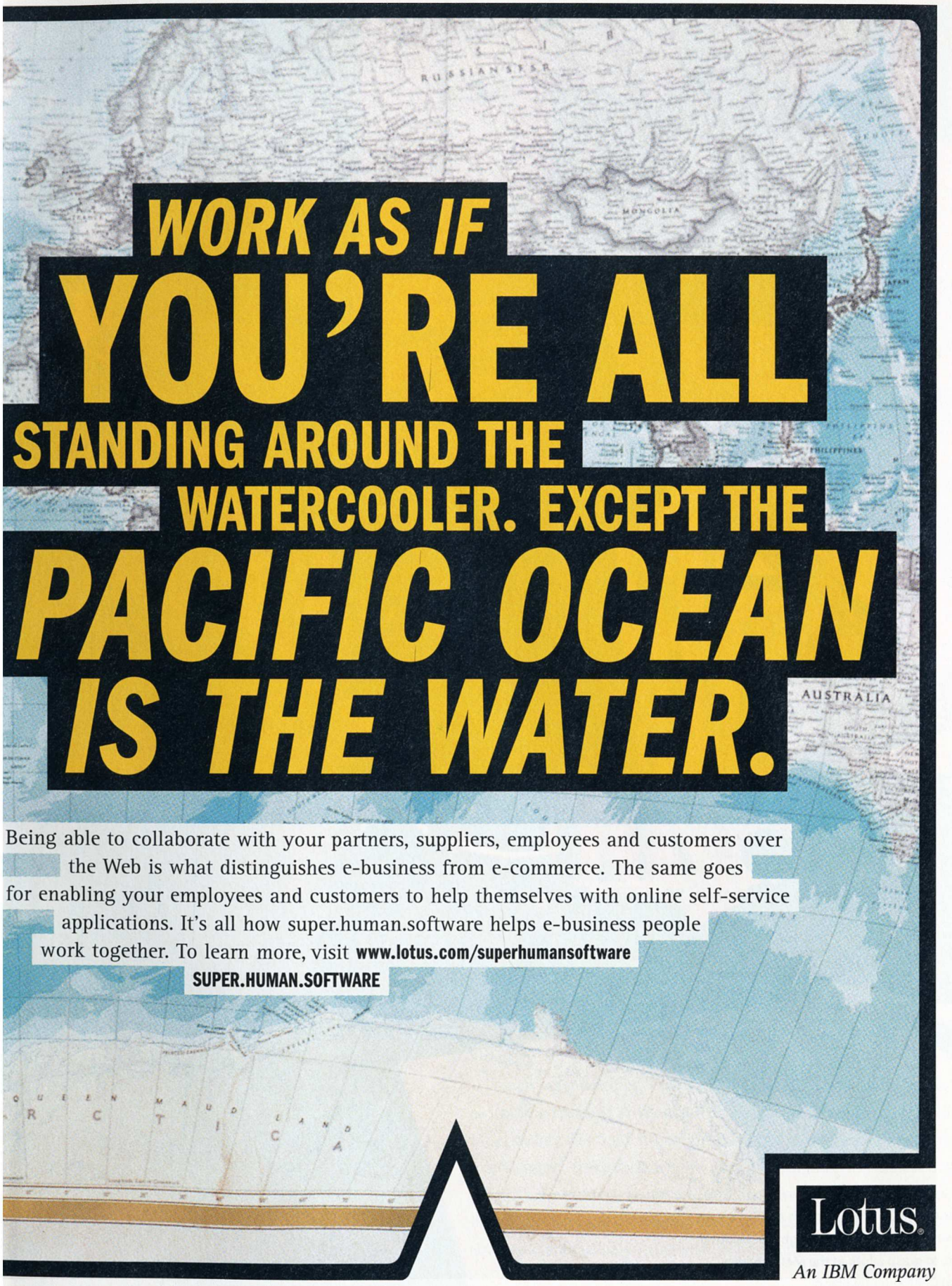
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Thinking cap: Quadriplegic Jim Jatich uses his brain waves, transmitted through electrodes in the cap, to grasp a fork at the MetroHealth Medical Center in Cleveland.

When two emerging technologies meet, paralyzed people can move their limbs—just by thinking about it. BY VICTOR D. CHASE

Mind Over Muscles

ON A COLD DAY IN LATE 1998, JIM JATICH, 51, SAT at a table in Cleveland, Ohio's MetroHealth Medical Center and donned a cloth beanie with dozens of wires protruding from its surface. He had been practicing twice a week over several months for this moment, and he was so intent on the task at hand that the magnitude of it didn't sink in until he emerged from the hospital later in the day.

"That's when it hit me," he recalls. "I got tears in my eyes, turned to my sister, and said, 'Damn, I actually moved my hand by thinking about it.'"

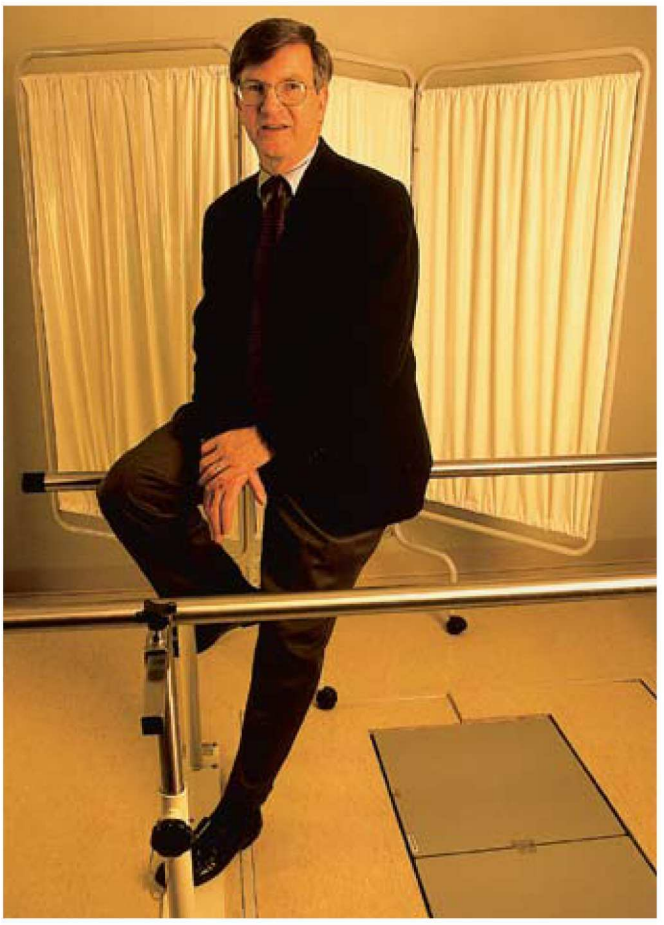
Jatich is a quadriplegic who lost the use of his hands and legs in a swimming accident 21 years earlier. But in a series of first-of-a-kind experiments that hold out the promise of a more normal life for the handicapped, researchers led by biomedical engineer P. Hunter Peckham of Case Western Reserve University have succeeded in re-establishing the damaged connection between Jatich's brain and body. Their strategy: combine two cutting-edge technologies into a system that uses

PHOTOGRAPHS BY ANNE HAMERSKY

brain waves to move paralyzed limbs.

The more advanced of the two technologies is functional electrical stimulation (FES), in which electrodes implanted under the skin are used to choreograph movement in the muscles of paralysis victims. For several years, Jatich has used a commercially available FES system known as Freehand; this "neuroprosthetic" allows him to open and close his hand and manipulate everyday objects like pencils and telephones. Normally, Jatich triggers his Freehand's mechanism with a shrug of his shoulder. Now, by combining FES with a second, much earlier-stage technology known as brain-computer interface (BCI), the Cleveland team has given Jatich rudimentary control over the Freehand using his brain waves alone.

Although this "thought-translation" system is still far from practical, other research teams are now pressing hard to develop implants able to capture superior control signals directly from the brain's motor cortex, the area where volitional movement is thought to arise. In what seems like a page torn from a William Gibson novel, such cortical implants have already been used to restore communication to two patients "locked-in" by severe paralysis *(see "Tapping the Life Within," p. 45).* And some scientists believe that using these signals to control robotic arms or FES systems may no longer be a distant prospect. "We're getting to a point where developments in neurosurgical and electrophysiological procedures and in microelectronics are making this feasible," says Miguel Nicolelis, a neurobiologist at Duke University. "This is not science fiction anymore."



Rehab pioneer: Neuroprosthetics designed by P. Hunter Peckham have restored limited motion to more than 100 paralysis patients.

Getting a Grip

PREVIOUS TO THE EXPERIMENT IN CLEVELAND, THE LAST TIME Jatich had thought his hand into motion was on a hot summer night in 1977. He and some friends had spent the day housepainting in Akron, Ohio, and decided to cool off with a swim in nearby Portage Lake. "I was the last one to dive in and I hit something," Jatich recalls matter-of-factly. "I saw stars and knew right away what happened. I was stunned and sank to the bottom, my face in seaweed."

In that split-second, Jatich went from being a healthy junior engineer at tire-maker Firestone to a C5-C6 quadriplegic. The spinal damage, between his fifth and sixth cervical vertebrae, left Jatich's legs totally immobilized, though he retained some shoulder and arm movement, and could raise his left wrist. According to the National Spinal Cord Injury Statistical Center, accidents cause about 10,000 spinal cord injuries in the United States each year. Of the estimated 200,000 paralysis victims in the United States, about half are paraplegics who've lost sensation and movement in their legs, and half are quadriplegics suffering from paralysis in all four limbs.

There's still no cure for paralysis. But the merger of neuroprosthetics and brain-computer interfaces could offer a more normal life for some patients.

As he lay convalescing in Cleveland's Highland View Rehabilitation Hospital, Jatich was approached by Peckham, then a young Case Western Reserve scientist seeking a volunteer to work with him on an FES system for restoring hand motion. Patient and researcher were embarking on lifelong quests for new spinal cord injury treatments. Jatich was inspired by necessity. Peckham's motivation originated in a magazine article he'd read in college about mechanical heart valves, which opened his eyes to the notion that "engineers can do something to help mankind." In graduate school, Peckham fell in with a group of biomedical engineers involved in early efforts to use electrical stimulation to restore function to skeletal muscles; "I became fascinated with it," Peckham says, "and that was the last time I thought in depth about the vascular system."

FES experiments in the late 1970s and early 1980s were less than elegant. In his work with Peckham, Jatich saw wires threaded through his wrist with a needle in a trial-and-error hunt to provoke movement in the correct muscle groups. The protruding electrodes were connected to a computer in Peckham's lab, which fired off signals to the muscles in various configurations. The computer was large and stationary, and the electrodes broke frequently, yet Jatich's hand did move, and he was able to pick up objects, though his control was far from adequate.

It took two decades for Peckham to perfect his invention, now known as Freehand, and which in 1997 became the first implantable FES device to receive U.S. Food and Drug Administration approval for wide use. About 160 quadriplegics now use Freehand to write, feed themselves, perform personal grooming, and, in some cases, even manually operate a computer. The Cleveland company founded by Peckham to sell the device, NeuroControl, has just raised $4.5 million in venture capital money to step up marketing of Freehand and a bladder-control device called VOCARE.

Today, Jatich uses Freehand to close his right hand by activating a "joystick" taped to his left shoulder. Pushing his shoulder forward, the joystick signals a computer carried on his wheelchair, which then sends a series of timed electrical pulses to eight platinum electrodes implanted next to nerves feeding the muscles that close his hand. Separate shoulder commands let Jatich lock the grip, or release it.

Once a person who needed help to eat and thought his career was over, Jatich is now largely self-sufficient and has even begun an in-home business creating computerized engineering drawings. "I'm using my hand again. I'm picking up a fork to feed myself, and picking up a pen to write again," says Jatich. "That's a big emotional change in my life."

Think About It

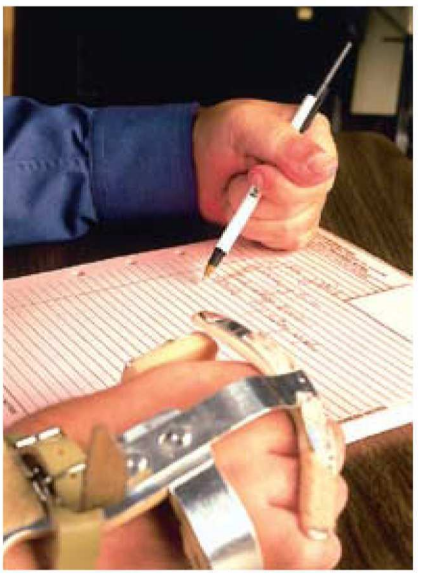
IN THE PROCESS OF DEVELOPING FREEhand, Peckham turned Cleveland into the world's focal point for FES development. In 1990, he was instrumental in founding the Cleveland FES Center, a consortium of medical centers where researchers are now driving Freehand technology in new directions. Current projects include systems that allow paraplegics to stand and move a few steps on their own, research aimed at finer muscle movement using more electrodes, as well as what Peckham terms "alternative strategies for control" that can bring more natural dexterity to paralyzed people. The most dramatic of these alternatives is mind over matter: direct brain-control.

As early as the 1960s, scientists discovered that people can control certain components of the electrical signals emitted by their brains, which are recorded from the scalp as electroencephalograms (EEGs). EEGs could therefore be used to issue simple commands to electronic devices, but the technology remained largely a laboratory curiosity. It's been explored by the Air Force as a futuristic means for pilots to fly jet planes, and has more recently found a concrete application in helping patients with severe paralysis to communicate via computer.

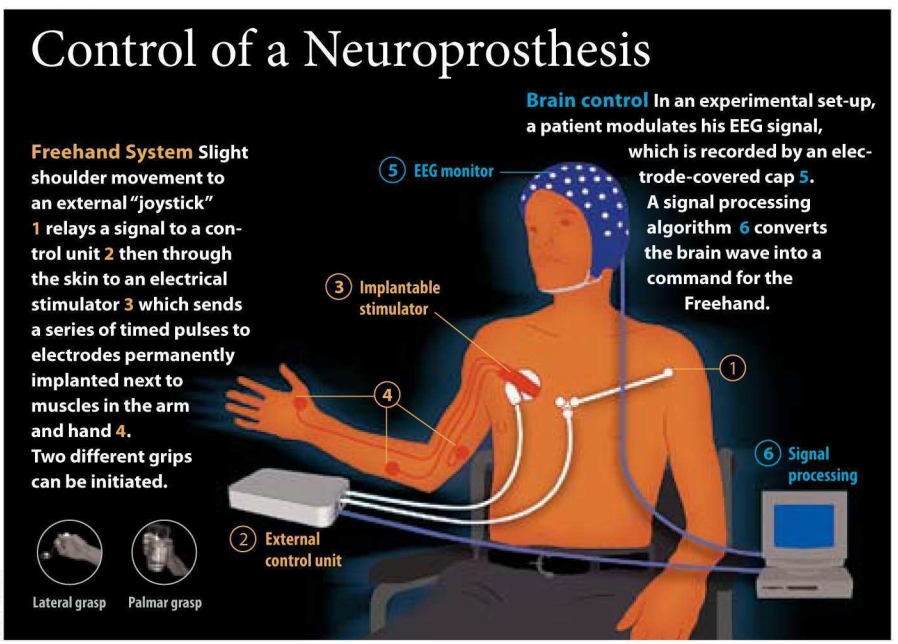
Starting in 1997, Peckham says he and graduate student Richard Lauer began attempting to use brain-computer interface technology to "acquire information from the brain and put it into the hand of a person." Their initial subject was Jatich, who agreed to wear what looks like an oversized, electrode-studded shower cap to help the scientists learn whether EEG signals could control his Freehand system directly, without the usual shoulder controller.

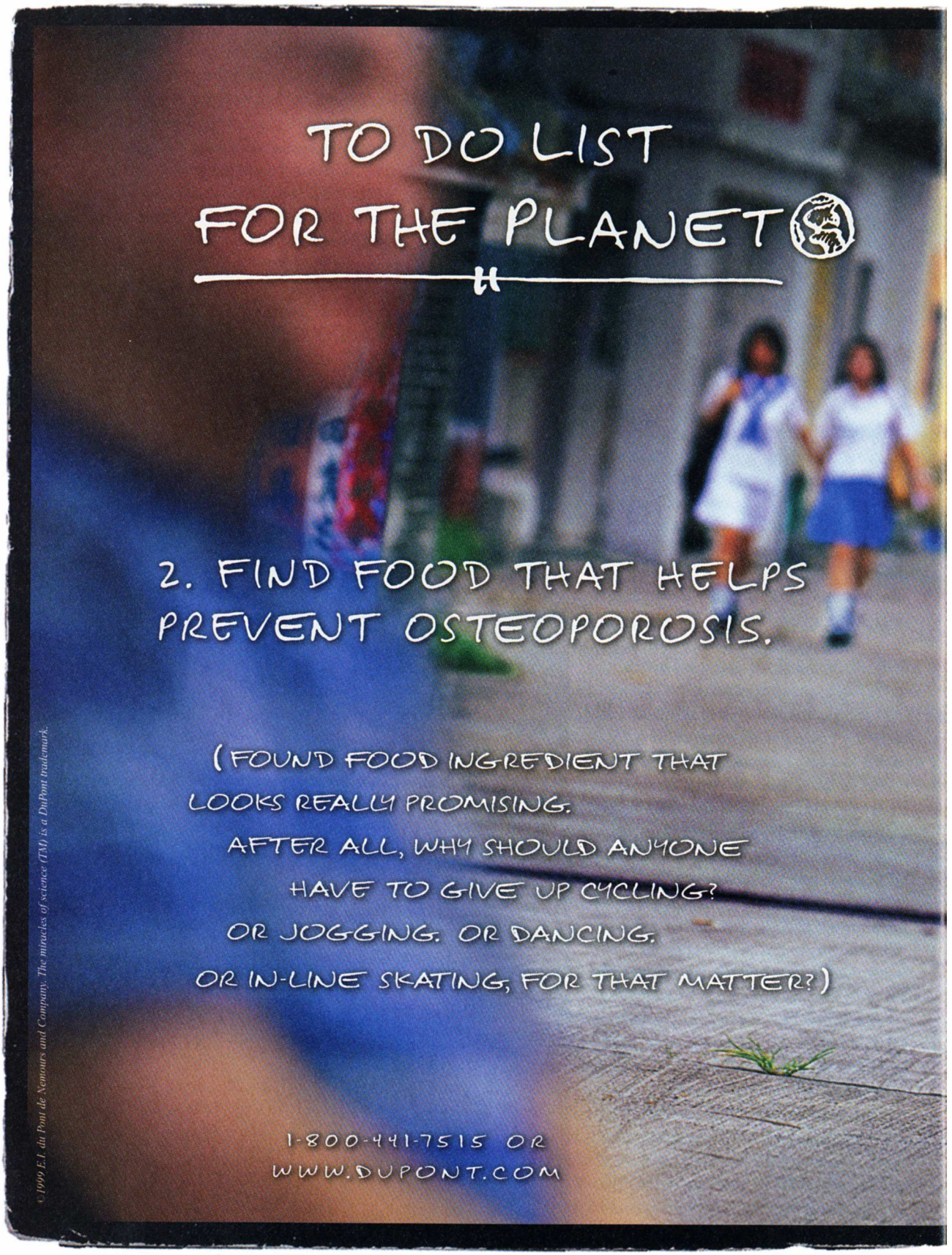
Lauer and Peckham zeroed in on a component of the EEG known as the beta-rhythm, which Jatich began learning to modulate in order to move a cursor on a computer screen. Thanks to the phenomenon known as biofeedback, Jatich was able to use the cursor's movements to gain conscious control over the strength of the beta-rhythm, even though he'd previously been completely unaware of it. After a dozen training sessions, Jatich had learned to move the cursor simply by thinking of a particular direction. The next step was to convert the cursor signal into a command for Jatich's Freehand. The switch-over went smoothly: Jatich soon was opening his hand by thinking of moving the cursor up. By thinking down, he closed it. Since then, Jatich has learned to manipulate objects including a glass and a fork.

Dramatic as these results are, Peckham cautions that all Jatich is doing "is using the signal to tell his hand to close. It's a very rudimentary control." Indeed, thus far, EEG-control remains slower and less versatile than the shoulder controller. For instance,



Holding on: Jim Jatich's Freehand neuroprosthetic system lets him grasp a can of soda. A research-stage implant in Jatich's left hand provides finer muscle control.

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because the beta-rhythm provides only a single on/off signal, Jatich still can't lock his hand into position—instead he's got to continually think "hand closed." "We're saying pick up this fork, stab something and raise it to your mouth," explains Peckham, "but if the task was eat a meal, which requires holding onto the fork for an extended period of time, we would not have the same level of success."

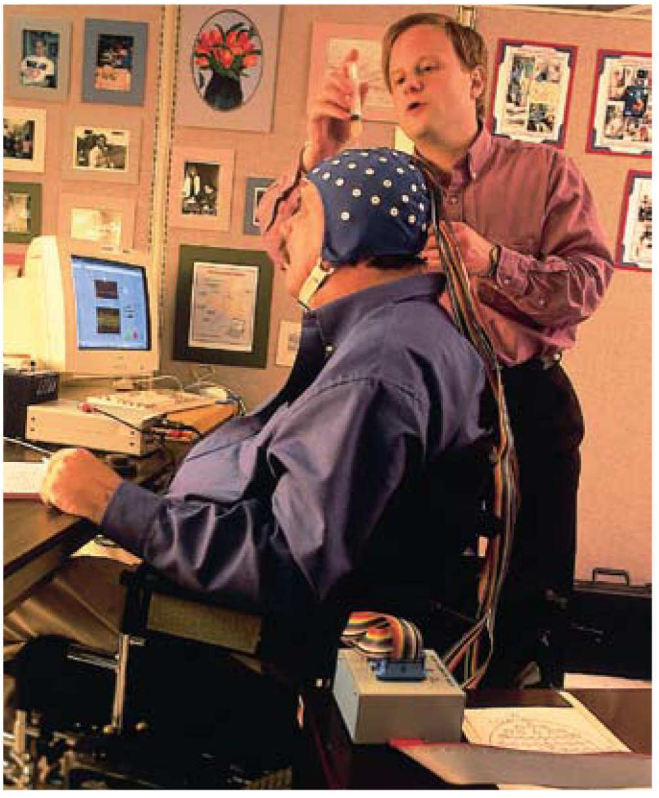
Still, the initial results are "fairly promising," says Bill Heetderks, a physician who directs the National Institutes of Health's Neural Prosthesis Program, which, along with the Veteran's Administration and the National Science Foundation, provides the majority of the grants that support FES and BCI research. As Heetderks points out, only about ten percent of quadriplegics have enough shoulder and arm movement to operate Freehand. He says EEG control might allow people with injuries higher on their spinal cords, like the actor Christopher Reeve, to benefit from neuroprosthetics as well.

Over the next year, says Peckham, his team will be trying to establish whether or not the EEG signal is good enough to give full movement to current Freehand users. Confident, yet cautious, Peckham notes, "We are not certain yet whether the control is, in fact, fast enough and natural enough."

Monkey See, Robot Do

PART OF WHAT LIMITS EEG SIGNALS IS THAT WHEN ONE THINKS about moving a cursor, or an arm, thousands of brain cells fire off simultaneously. Surface electrodes pick up all of the brain waves at once in a cacophony of electrical activity. That's why a growing number of researchers are working on what's termed "invasive" brain-computer interfaces. By tapping directly into the motor cortex, they hope that they can get past the EEG's cocktail party chatter to tune into individual neurons, an advance they think could be key to helping the paralyzed operate FES devices.

Already, a number of animal experiments are suggesting this is precisely the case. In a startling result published last summer in the journal *Nature Neuroscience*, Duke's Nicolelis and John Chapin, a neuroscientist at Hahnemann University in Philadelphia, reported that they had been able to get a rat to operate a robotic lever in real time via two dozen electrodes implanted in the area of the motor cortex that controls paw movement.

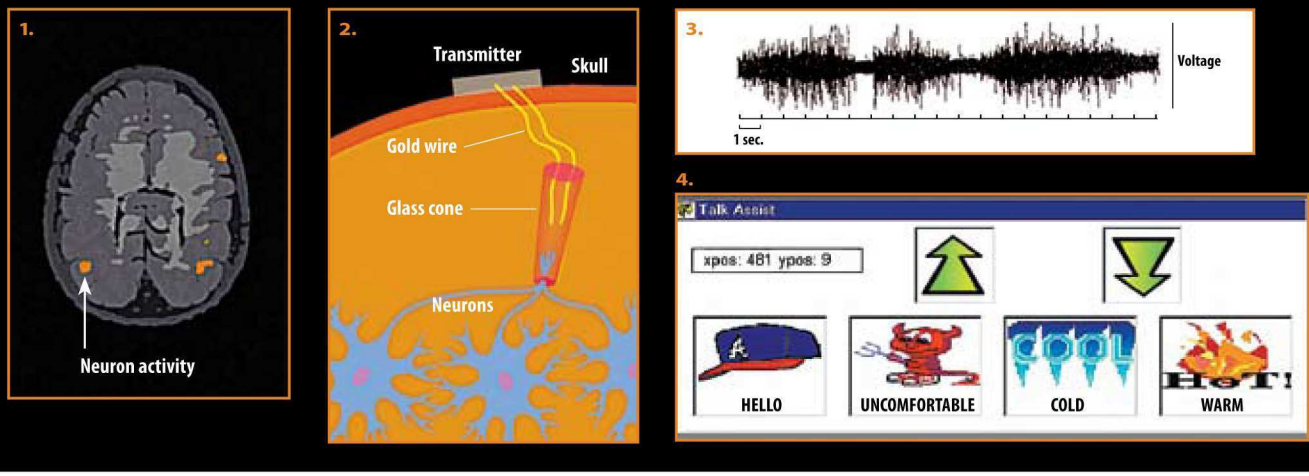


Body electric: Case Western graduate student Richard Lauer (rear) squirts contact gel onto Jim Jatich's scalp to capture his EEG signal.

Several academic teams, including Chapin's as well as groups at Brown University and the California Institute of Technology, are trying to reproduce similar results in monkeys, whose brains are more like our own. So far, some of the most exciting results have come from neurophysiologist Andrew Schwartz at San Diego's Neurosciences Institute and collaborators at Arizona State University. Using dozens of hair-width

Unlocking a Mind *(see box, p. 45)*

1. A functional magnetic resonance image (fMRI) of the brain shows areas of neuron activity when a paralyzed patient imagines closing his left hand. 2. Neurons grow into an electrode implanted in the active region. 3. Measurements of neuron firing rates provide a control signal that the patient uses to move a computer cursor. 4. A computer program allows the patient to communicate basic needs.



BETSY HAYES

electrodes implanted in the brain of a rhesus monkey, Schwartz simultaneously recorded signals from about 50 individual neurons, which he fed through a data-crunching algorithm to a robotic arm in a separate room. "And we see," he says, "that the robotic arm moves close to the same trajectory that the monkey moved its arm." A split-screen movie of the result can be seen on the Web at www.nsi.edu/motorlab.

This feat is possible even though scientists still know very little about how the brain creates movement. The trick, Schwartz explains, is that although there are millions of neurons in the motor cortex, measuring the "firing rates" of just a few cells can give a surprisingly accurate picture of where and how fast the monkey's arm is moving. "It's like doing a survey. You're not going to get every person, but if you have enough samples you can get a pretty good idea of what's going on," he says.

Although Schwartz's primates were unaware of the robot mimicking their movements, he's now working on an experiment in which he'll challenge restrained monkeys to use a thought-driven arm to feed themselves. A positive outcome would be proof-of-principle that a cortical signal could give quadriplegics precise control over FES devices like Freehand. In fact, Schwartz predicts that a rudimentary brain-activated robotic arm will be ready for human use within five years.

Even a successful human test won't automatically translate into a working device. The development of invasive recording electrodes has been going on for some 30 years, but is still plagued with problems. In animal studies, signals from implanted electrodes tend to diminish over time, which may be due to scar tissue or shifting of the electrode caused by the brain's normal movement within the skull. Schwartz calls "the long-term survival of the electrodes" a key problem, and admits that the Teflon-coated stainless steel wires he uses are "really crude devices."

But improved electrodes is an engineering challenge that several teams are already looking to meet. Some of the most successful work to date has been accomplished by neurologist Phillip Kennedy of Atlanta, Ga., who was the first to implant cortical recording electrodes in a human being. And the Duke group has helped develop a matrix of 16 electrodes, just a square centimeter in area, which Plexon Inc., of Dallas, Texas, is now manufacturing. The electrodes are working well in primate experiments, but Nicolelis adds that "we need to evolve to a new generation." Already looking ahead to applications in people, Duke is designing a telemetry chip to connect to the electrode array and transmit neuron recordings to an external computer, without wires coming through the skull.

Thoughts and Dreams

DESPITE THE PROGRESS TO DATE, SCIENTISTS DON'T YET KNOW whether BCI and FES devices will ever come together to restore precise natural movement to paralyzed human limbs. For instance, even given a perfect cortical signal, FES researchers might be unable to make full use of it. Nicolelis warns that, "It's a complex problem to coordinate the muscles to produce the kind of spatial-temporal patterns you need."

And yet there is a reserved consensus among FES experts that many of the same technological innovations that are driving BCI research, in particular better microelectronics and improved electrodes, are also paving the way for an increase in the speed of FES development. As Peckham puts it, "I think you could make a pretty good argument that we're just getting the tools available now to make substantial clinical impacts."

Today, spinal cord injury is still a condition without a cure. Yet every paralysis victim dreams one will happen soon enough to make a difference in his lifetime. Where will the cure come from? The biomedical engineering approach expressed in Freehand has already achieved what millions spent on drug research and recent scientific progress in regrowing nerve cells haven't yet: a degree of normality in the lives of quadriplegics such as Jatich. Now the merger of neuroprosthetics with brain-computer interfaces, while still in the research-prototype stage, promises another stride toward helping people whose bodies are immobile, but in whose minds hope steps lively. ◊

Tapping the Life Within

Imagine being wide awake and yet completely unable to move. For almost 2,500 patients in the United States who are victims of severe strokes and conditions such as amyotrophic lateral sclerosis (Lou Gehrig's disease, or ALS), this scenario is a real-life nightmare. Bound and gagged by near-total paralysis, these patients must be fed intravenously, rely on machines to breathe, and in some cases, must have their eyelids taped open so they can see. Perhaps worst of all, although they remain aware, these "locked-in" patients cannot communicate.

Over the last two years, neurologist Phillip Kennedy and his colleague Roy Bakay, a neurosurgeon, both with the Department of Neurosurgery at Emory University, Atlanta, Ga., have uncorked the thoughts of two locked-in patients with "neurotrophic electrodes" implanted into the motor cortex areas of their brains. Neurons grow into the devices—glass tubes containing minuscule low-impedance wires—allowing the researchers to measure the cells' electrical activity *(see "Unlocking a Mind," opposite page).*

The second patient, John Ray—who goes by JR—is a 53-year-old who had been a drywall contractor until a 1997 brainstem stroke rendered him locked-in. "He can laugh and cry, but he can't speak; he can't move. Yet his attitude is absolutely incredible. He's got great energy," says Kennedy, who with Bakay implanted two electrodes into JR's brain in March of 1998. Since then, their patient has learned to use his thoughts to operate a computer program designed by Georgia State University that lets him select letters and produce audible responses. Kennedy has formed a company called Neural Signals to fund further development of the technology.

Researchers in the United States and Europe have also released locked-in patients with noninvasive systems that use electrodes placed on the outside of a person's skull to pick up EEG signals. "We have several patients who are able to communicate and write letters," says psychologist Nils Birbaumer of the University of Tübingen, Germany, who works with ALS patients. Although Kennedy believes the invasive implants promise a superior signal, the results of both approaches have, thus far, been surprisingly similar—three or four characters per minute.

Although that may sound agonizingly slow, even a few words can make a big difference. "This is probably one of the most terrifying states a human being can be in," and many locked-in patients die "because of hopelessness and not because of disease," Birbaumer says. "Most of our patients are now much older than was predicted by their physicians because their psychological health is improving."

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Fiber Optics to the Home

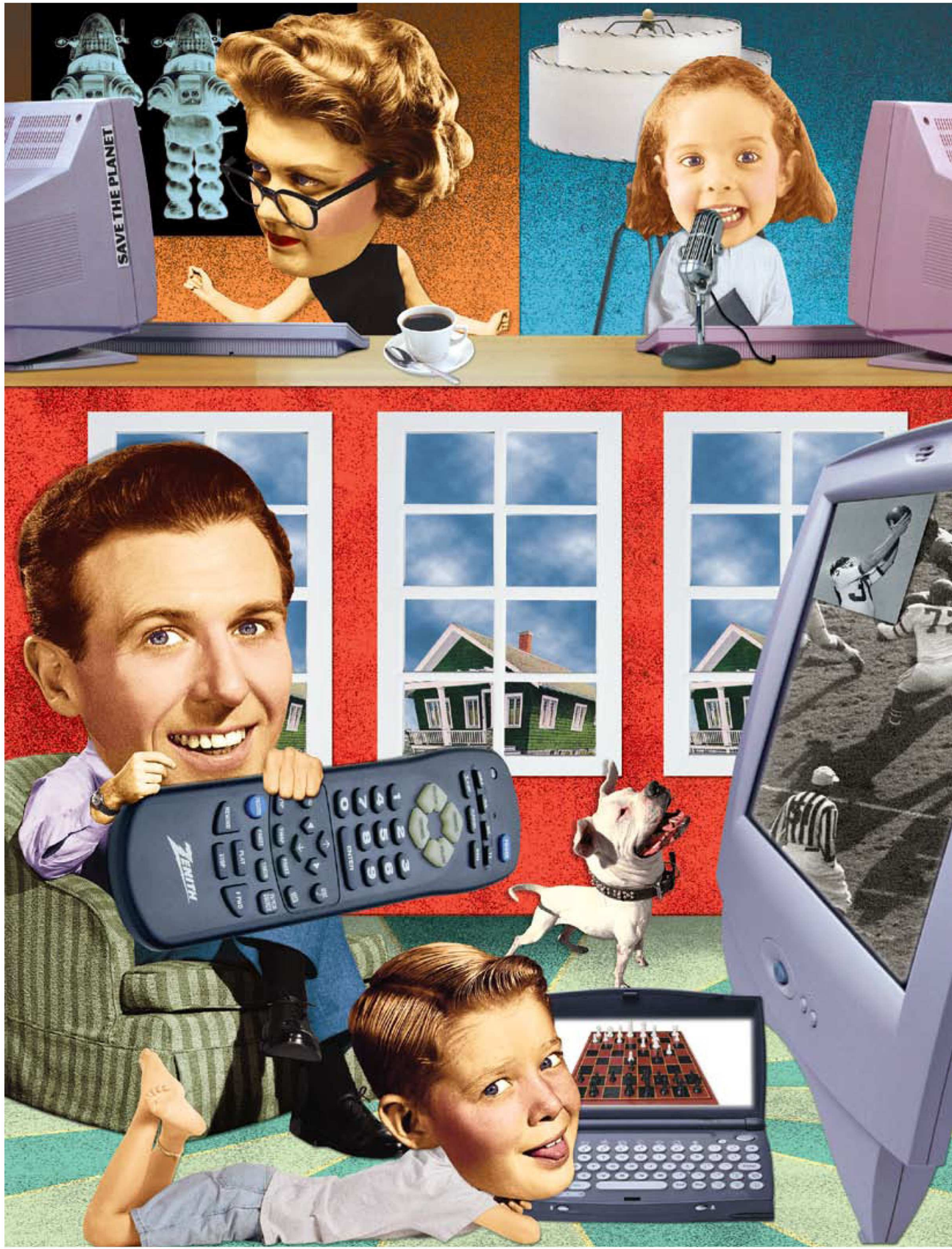
Fiber optics has helped push the **telecommunications** system into **hyperdrive**. But only when fiber connections reach all the way into the **home** will the technology's **promise** be fully realized. BY JEFF HECHT

ILLUSTRATION BY FRANCISCO CACERES

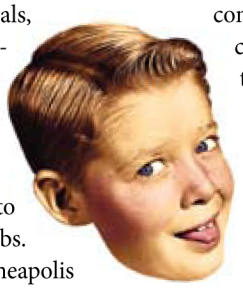
It's 2020, and the Gernsbacks have settled into their new home. Dad is watching football on the flat-panel screen in his home theater, but he isn't satisfied with standard broadcasts. The Custom SuperView channel lets him select four current or instant-replay views from any of a dozen high-definition cameras stationed around the stadium. Mom is upstairs working, using telepresence to control a robot cleaning up a toxic waste site in New Jersey. Their teenage son is playing three-dimensional chess with a friend in Paris; a supercomputer in New York calculates the data used to show the pieces on their digital holographic displays. His sister, meanwhile, is practicing with a choir made up of people who live in a dozen cities in North and South America; a computer in Mexico City merges their voices and transmits the music back to their computers in real time, while creating an array of their faces on a single screen.

Some of this technology can be found in well-equipped laboratories today, but not in homes. Today's information superhighway lacks the bandwidth to deliver the required signals, deteriorating into a muddy footpath as it reaches your front yard. Most homes connect to the Net through modems that deliver at most 56,000 bits per second. High-end users are switching to cable modems and digital subscriber lines (DSL) that can carry a few megabits per second. That's a big leap ahead, but hardly enough to satisfy the Gernsback household: The scenario described above would demand 100 to 200 megabits per second.

I named our futuristic family after Hugo Gernsback, a technophile and writer who published America's first science-fiction magazine in 1926. But in just a couple of months, some residents of Palo Alto, Calif.,



will get a taste of these powers when their homes are wired directly to optical fibers. Palo Alto is not alone on the fiber forefront. Last fall, BellSouth began stringing fiber to up to 400 homes in Dunwoody, Ga., an affluent suburb just north of Atlanta. Unlike other fiber-to-the-home systems that have been rolled out in the past as field trials, Dunwoody is a permanent installation. North of the border, Futureway Communications, a new Canadian phone company seeking a niche offering high-end services, is stringing fiber to homes in five Toronto suburbs. Optical Solutions, a young Minneapolis company, is supplying Futureway with fiber connections for 20,000 homes, and has sold hundreds of home links to other small phone companies.



Competing With Copper

These leading-edge systems are still rare. Most telephone and cable television companies rely on fiber only as a "backbone" technology for piping signals between their own facilities. In fact, fibers are the standard links to and from the switching offices serving each community, and often stretch from there to large business customers or neighborhood distribution nodes. A single pair of fibers now can carry up to hundreds of gigabits per second, with each fiber transmitting separate signals at dozens of wavelengths in one direction. Yet the rest of the distribution network is virtually all copper—that's an investment worth well over $100 billion and phone and cable companies are not eager to abandon it. Late last year, regional telephone company SBC Communications announced a three-year, $6 billion fiber construction program in its service area in the western United States.

But conventional wisdom holds that running fiber all the way to a home is too costly, so SBC's fibers will stop at distribution nodes that typically serve hundreds of customers. Data will still slog into the home itself on old-fashioned copper. It's as if a relay team of Olympic-class sprinters had to rely on a geriatric patient for the final leg of the race—known in telecommunications lingo as "the last mile."

Phone and cable companies each promise a different cure for the World Wide Wait suffered by home users of dialup modems *(see "Battle of the Last Mile," p. 52).* Cable systems deliver up to 36 megabits per second through the same coaxial cable that pipes CNN and HBO to the television set. The phone companies have devised DSL as a ploy to trick ordinary copper wire into behaving as if it were a fatter info-pipe, carrying up to several megabits per second.

People who switch from ordinary Net connections to cable modems typically traverse an arc of experience that begins with delight: The link is always on, just like electricity in a socket, and information flows at speeds that leave dialup modems in the dust. Then the drawbacks become apparent: cable bandwidth is shared among a group of users, so the lightning-fast connections experienced at first start to drag as more of your neighbors sign on. Security is another issue; if file sharing is enabled—a common default setting—everyone on a cable modem line can access your files. DSL has a different problem. The higher signal frequencies that carry DSL's digital data fade as they travel through copper wire, restricting these connections to homes within about five kilometers of cable from a phone switching station. Wireless systems—an emerging high-bandwidth alternative—can suffer blockages from bad weather, trees and buildings.

If the past is any guideline, moreover, demand for bandwidth will soon outstrip the capacity of these jury-rigged alternatives. Already, today's image-intense Web sites crawl when viewed at 56 kilobits/second. Full-motion video, for example, appears as a jerky, low-resolution picture in a corner of the screen. The need for higher capacity into the home is likely to intensify as companies roar ahead with e-commerce. Why show just a static picture and product specifications for a refrigerator if you can have a top salesman deliver a video pitch while demonstrating it on the screen? A reasonable target may be 100 megabits/second, which should enable full-screen, full-motion video and would probably satisfy the Gernsbacks. Then again, satisfaction is a moving target. Bandwidth is a drug; once you're hooked, you only want more. A single optical fiber can easily carry more than 600 megabits/second to individual users—far beyond the capability of either DSL or cable lines. Indeed, DSL and cable modems would whet consumers' appetites by giving them a taste of bandwidth plenty that only fiber can satisfy.

Now is the time to make that investment, at least for new installations, argues Asim Saber, president of Optical Solutions. Saber says that installing fiber will cost an extra 15 percent to 25 percent, but claims that the payoff will come in a few years as bandwidth demand soars. Better, he says, to spend more now than be forced to rip up the sidewalks in 8 or 10 years to add capacity.

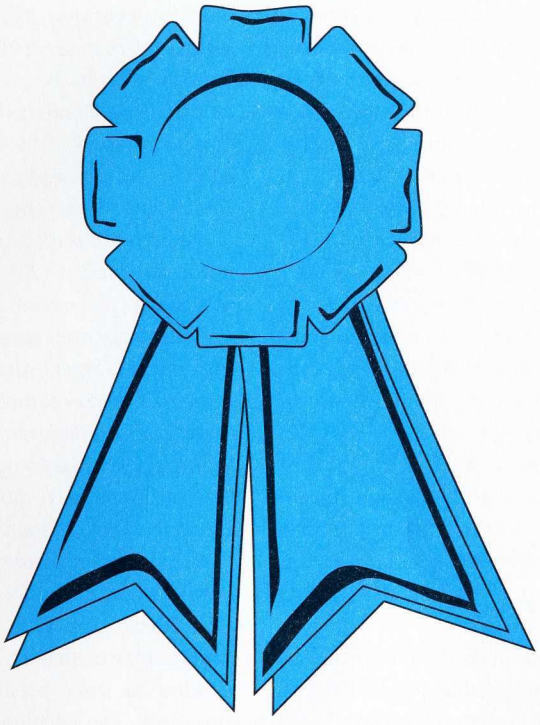
The explosive growth of the World Wide Web has made millions of people crave bandwidth—a commodity they scarcely knew existed before.

Different This Time?

It's not as if no one has tried fibering homes before. Skeptics point to earlier field trials that have failed to find much of a home market for fiber's tremendous bandwidth. Japan's Ministry for International Trade and Industry sponsored the first, which began service to about 150 homes in 1978. The experiment consumed a staggering $80 million over several years, but—along with similar trials in Canada and France—failed to identify compelling new services that would justify the high cost of installing fiber.

A decade ago, BellSouth and several other U.S. phone companies thought they had found a high-bandwidth activity that consumers would pay for: video on demand. Dozens of homes were fibered in trial systems around the country, but the spark never caught: The level of consumer interest was deemed insufficient to justify the purchase of costly video servers and fiber equipment. Cable companies quickly countered by adding more channels and pay-per-view services to their existing coaxial cables. But a funny thing has happened since the last time fiber was reeled out to domiciles: the Internet. The explosive growth of the World Wide Web has suddenly made millions of people crave bandwidth—a commodity that they scarcely knew existed a few years before.

For the coming decade, fiber-watchers in the United States will want to focus their



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attention on the southeast. BellSouth—the phone company that serves the region—"is leading the charge in North America" for fibering the home, says Richard Mack, vice president of KMI, a Newport, R.I.-based market research firm. The interest in new technology reflects the rapid growth of its service area. Most new communities want buried utilities, and it is far cheaper to lay extra fibers for future expansion now than to return years later to dig up streets and yards to replace obsolete cables.

Dunwoody residents will continue to receive voice telephone service over existing copper lines, and customers will be offered two new services over fiber. One is DSL-grade data transmission for $50 to $60 a month. The second is a video service offering 120 digital and 70 analog channels. Next year, the company expects such fiber systems to become standard for large new subdivisions. By then, customers with fiber connections in their homes could install the equipment themselves. "We don't have to roll a truck at all," says Dan Spears, research director at BellSouth Science & Technology.

BellSouth admits that the Dunwoody fiber system is costing more to install than copper, but says the goal is to gain experience with the technology. As the cost of fiber to the home comes down, BellSouth "will deploy it in new build situations as we're now deploying fiber to the curb," says Dave Kettler, vice president of BellSouth Science & Technology.

Scattered groundswells of interest in home fiber connections are appearing in affluent U.S. towns. In Concord, Mass., the Concord Communications Infrastructure Committee, a town advisory panel, has suggested the town build its own digital fiber network to homes. Cable modems have yet to reach the town, many homes are outside the reach of DSL, and both have limited room for expansion, complains Marc Daigle, an engineer and member of the committee.

Palo Alto's city council has already approved spending $380,000 to build a fiber network serving nearly 700 homes in an older area near the city center. Residents will get connections at 10 or 100 megabits per second. They will pay about 70 percent of the cost, including monthly charges plus installation fees of $1,200 or $2,400, depending on data rate. More than 70 people signed up before the city had set a firm price, says Manuel Topete, who is managing the fiber system for the city's utility department.

The system will offer data transmission at otherwise unobtainable speed. "The trial is all based on Internet delivery," says Michael Eager, a Palo Alto consultant active in the project. "I don't think people would have been significantly interested if we were just talking about 500 channels of television."

Optical Solutions also has found strong interest. The company has sold fiber-to-the-home equipment to a dozen carriers in seven states, says president Asim Saber—plus the order from Futureway in Concorde, Ontario, for hardware to serve 20,000 homes in five Toronto suburbs. Founded in 1994, Optical Solutions accelerated its growth from 13 employees in late 1998 to 65 a year later; Saber expects a head count of 120 by later this spring. Last year Optical Solutions, which is betting its future on fiber to the home, also landed a $16 million investment in a private placement.

Futureway represents a new but promising market for Optical Solutions—new phone companies competing for business by offering high-end services unavailable from the big established companies. Similar ventures are starting to pop up elsewhere. In December, WideOpenWest of Littleton, Colo., announced plans to build fiber-to-the-curb systems in the Denver and Portland, Ore., areas. Optical Solutions' other customers are independent phone companies seeking to offer broadband services in rural areas. Rye Telephone of Colorado City, Colo., is installing fiber to 500 homes in a

Battle of the Last Mile

TECHNOLOGY	HOW IT WORKS	CAPACITY (MBIT/S)	ADVANTAGE	LIMITATIONS
Fiber to the home	Fiber carries data to homes. Could also carry broadcast video, either in same signal or at other wavelengths.	Several hundred, up to 1,000	Highest speed	■ Cost of construction
Digital subscriber line (DSL)	Transmits digital data on phone lines at frequencies higher than those used for voice. Frequencies are separated at the home. Individual homes get dedicated lines.	Downstream: 6-8 Upstream: up to 1.5	Can use existing phone lines	■ No service for homes more than 5.5 km from phone switching node ■ Top speeds possible only on short lines ■ Not available for all phone customers
Cable modem	Data travels to home on TV (coaxial) cable in a frequency band used for one video channel. Upstream transmission is at a lower frequency or on phone wires.	Downstream: typically ~1 Upstream: typically 0.1-0.5	Uses existing coaxial cable	■ Individual data rate drops with number of users ■ Poor security ■ Not available on all cable systems
Wireless (terrestrial)	Local antenna broadcasts microwaves, picked up by home antenna. Broadcasts video signals, and can transmit data.	Comparable to DSL	No cable installation	■ Multipath interference from buildings ■ Trees, terrain and rain can block signals ■ Interference possible from other cells ■ Signals travel limited distance (like cell phone)
Wireless (satellite)	Satellite broadcasts data signals; individual receivers pick off their signal. Might be added to direct broadcast satellite service, or to mobile low-earth-orbit service such as Teledesic.	To be defined	No cable, no local broadcast antennas	■ Better suited to broadcasting because of large satellite coverage area ■ Limited data rates likely

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sprawling 80-square-kilometer community called Hatchet Ranch. DSL can't handle those distances, and cable companies typically avoid such sprawling areas.

Standardizing Flexibility

For fiber optics to infiltrate a significant number of homes, telephone companies need to settle on technical standards. Just such an effort is under way. Representatives of 20 companies—including British Telecom, BellSouth, France Telecom, Nippon Telegraph and Telephone, GTE and SBC—have teamed to devise a Full Service Access Network (FSAN) running from telephone-company facilities to homes and businesses.

FSAN has already been accepted by the International Telecommunications Union and could accelerate the deployment of fiber to the home by providing a set of standards for mass-produced transmission equipment. The FSAN architecture covers a range of fiber uses, from carrying signals to neighborhood nodes and business customers to serving individual homes. FSAN could therefore allow fiber to infiltrate the network piece by piece.

That's important, because fiber is inching its way toward the home. SBC Communications' $6 billion Project Pronto will bring more than 20,000 kilometers of new fiber cable, extending the optical network to within 2.7 kilometers of most of the homes the company serves. SBC isn't alone; US West is laying fiber to within 1.2 kilometers and Bell Canada to within 900 meters, says Claude Roman, an analyst at market research firm RHK in South San Francisco.

And even before Dunwoody, BellSouth was routinely running fiber down every street in new developments. By the end of last year, the company had installed a hybrid fiber/copper service for half a million homes. Buried fiber cables run to service boxes that sit like fat, square fire hydrants along the curb, and copper wires fan out from each box to several homes. In Dunwoody, the company is "overlaying" fiber—stringing it in parallel with existing copper wires to homes.

FSAN makes this expansion easier with a design called a "passive optical network." The idea is to keep costly and sensitive active components, such as transmitters and receivers, on the ends of the system. Instead of directing signals through intermediate switches, the system simply divides the light among as many as 32 output fibers. No components between the central switch and the end of the fiber require electrical power, helping reduce construction and maintenance costs.

Upgrades to an FSAN system should be easy, generally entailing changes only of the equipment at the ends of the fiber. Data speeds can be boosted by dividing fiber capacity among fewer customers. In the longer term, each fiber might carry one wavelength channel per customer—a technique known as wavelength multiplexing *(see "Wavelength Division Multiplexing," TR March/April 1999).*

As companies **roar** ahead with e-commerce, the capacity required will outstrip that of **jury-rigged** copper alternatives.

The companies that developed the FSAN standard—among them Lucent Technologies, NEC and Hewlett-Packard—stress its adaptability. Some already are designing products. "We're developing a system that will provide low-cost fiber access for small to medium business because we think that's where the most obvious prove-in is for fiber all the way to customers," says Ed Harstead, who manages fiber-to-the-home research at Lucent. Indeed, fiber-to-the-business sales will help drive down prices of hardware for more cost-sensitive applications—a key to launching home fiber systems. British Telecom and France Telecom, two of the companies behind the standard, are eager to apply FSAN to business subscribers; BT plans to run fibers to commercial districts, with fibers branching among businesses as they would among homes. Nippon Telegraph and Telephone, which has tested fiber to the home and is cooperating with BellSouth, is now concentrating on business customers as well. From a technical standpoint, "it's difficult to distinguish fiber to the business from fiber to the home," says Kenji Okada, supervisor of NTT Access Network Service Systems Labs.

Technical standards such as FSAN can't overcome all the hurdles that may impede the fiberization of homes. BellSouth has the advantage of serving a region that is undergoing rapid economic and population growth. That means lots of new housing developments, each one a relatively easy opportunity for fiberization because the ground is already dug up for laying all sorts of power and telecommunications infrastructure. That's not the situation in most of the United States, where installing fiber means new construction. Not to mention the headaches in Europe. BellSouth's Spears says a Telecom Italia colleague was amazed by a photo of a landscape stripped bare by a developer. Spears recalls the Italian told him, "When we go into Rome and start digging in the street, we may run into some artifact, and they put a fence around it and halt construction until archaeologists do their work."

The market for fiber to the home is young, and analysts shy away from forecasting its growth. "It's hard to make projections based on services that don't exist yet," says Jeff Kagan, an industry analyst in Marietta, Ga. In the short term, the biggest question mark is how U.S. consumers and cable operators will respond to digital high-definition television, which will gobble up bandwidth like nothing we have seen so far. In the long term, continued growth of the Internet will push digital demand upward. The static images common on many Web pages load slowly at 56,000 bits/second, driving demand for DSL and cable modems in the megabits/second range. As increasing numbers of Web-site designers yield to the temptation to display moving images, even these lightning-like hookups may begin to feel sluggish.

Extrapolating the 20-fold growth in bandwidth of the 1990s—modems jumped from 2,400 to 56,000 bits/second—leads to a projection that by 2020, 100 megabits/second will be routine. And that may be conservative. Adel Saleh, chief network architect at Corvus in Columbia, Md., says that 100 megabits/second could come to homes as soon as 2005. Saleh predicts that by 2010, wavelength multiplexed systems will provide bandwidth on the order of 1,000 megabits/second. With that kind of capacity, the biggest problem will be figuring out how to tap into our inner Gernsback. ◊

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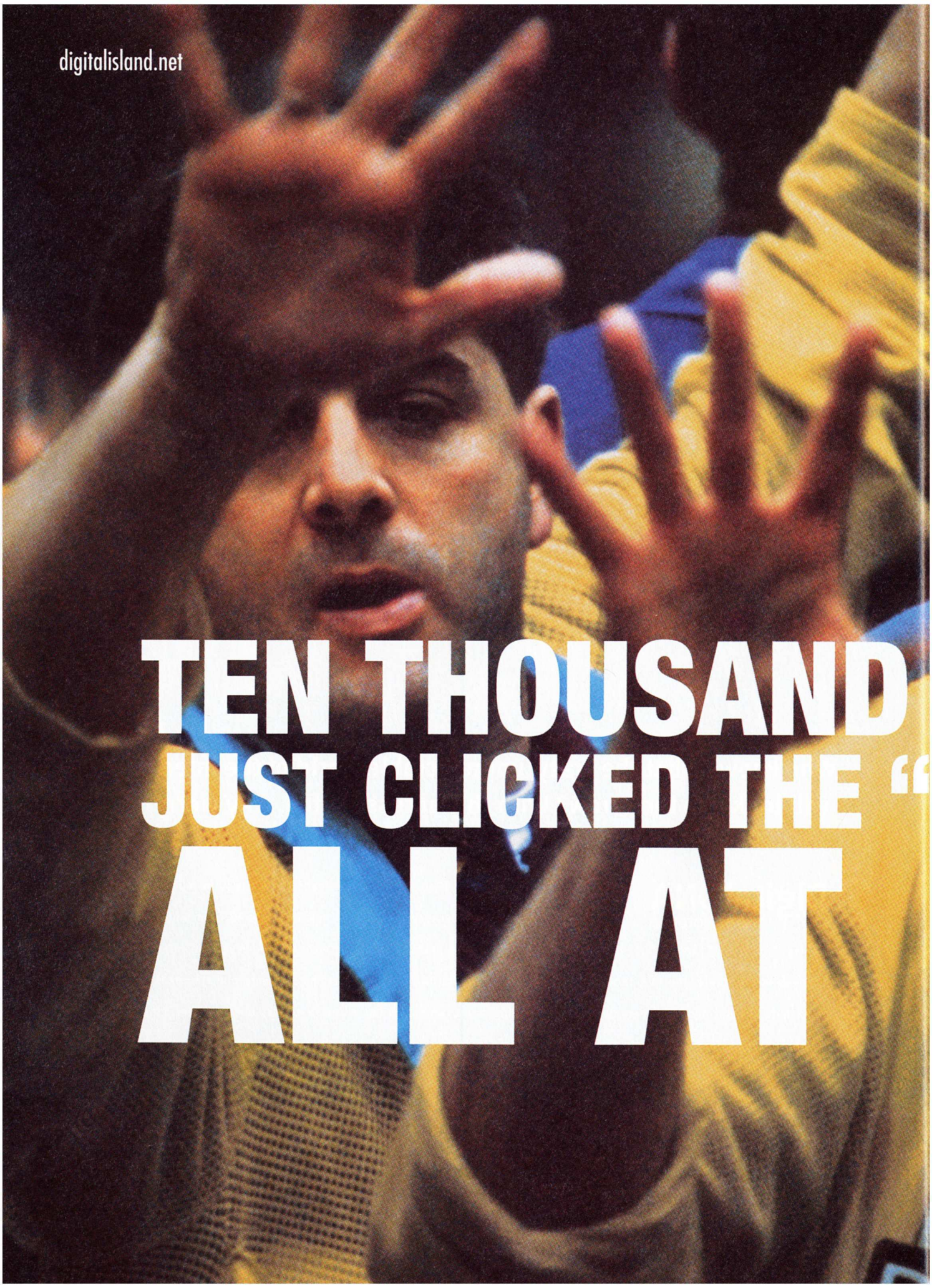
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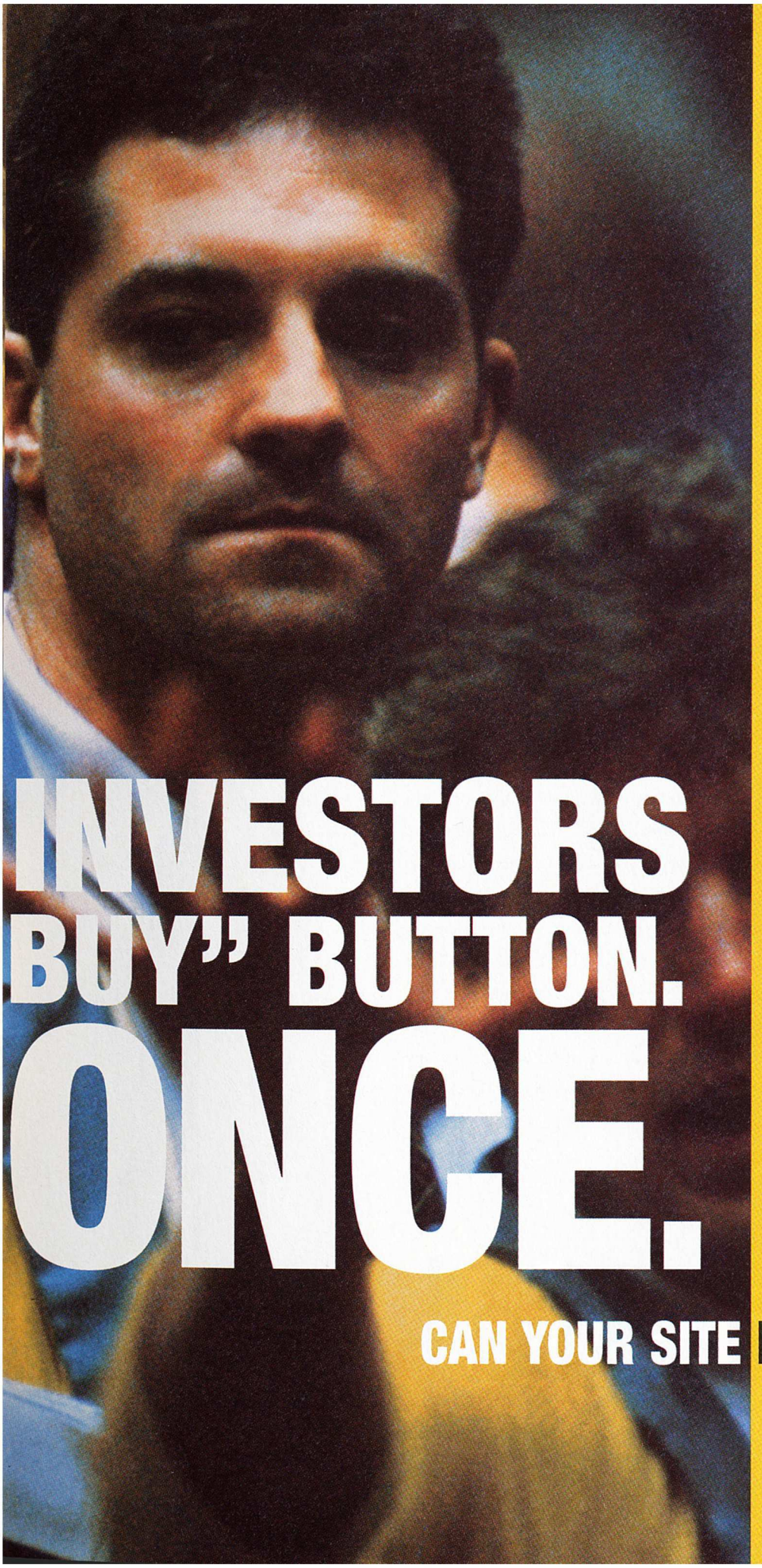

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High Stakes for Gene Therapy

After a decade of disappointment and a teenager's death, this experimental treatment faces a crucial test. Can it cure hemophilia?

BY KEN GARBER

PHOTOGRAPHS BY PATRICIA MCDONOUGH

KATHY HIGH DOESN'T SLEEP WELL THESE DAYS. A CHRONIC INSOMniac, the University of Pennsylvania hematologist now gets even less rest than usual. The reason? Stress. High does gene therapy.

These are not easy times for High and other researchers trying to cure patients with DNA. A few hundred yards down the road from High's Children's Hospital of Philadelphia office, over in Penn's main hospital, 18-year-old Jesse Gelsinger died last September after receiving gene therapy for a rare liver disorder. The teenager's death prompted highly public soul-searching by the gene-therapy community and intense scrutiny by the Food and Drug Administration. In January, the FDA put all of the human trials run out of Penn's Institute for Human Gene Therapy, including the one Gelsinger had volunteered for, on indefinite hold.

More quietly, and beginning even before Gelsinger's death, once-enthusiastic private companies have been backing off from gene therapy. Swiss drug firm Novartis pulled the plug on its flagship gene-therapy project, for brain tumors, in 1998. Biotech powerhouse Chiron virtually eliminated new in-house gene-therapy research last year. Of 14 biotech firms sponsoring gene-therapy trials in 1995, half no longer exist as independent companies, and the stock prices of most of the survivors have languished.

High risk, high gain: Gene-therapy researcher Kathy High.

Driven by the logic of the bottom line, many companies have decided it's more sensible to invest in proven drug strategies than in a highly experimental treatment that has so far yielded no definitive cures. At a conference last November, the Salk Institute's Inder Verma—a prominent researcher in the field—characterized gene therapy's successes to date as "almost nonexistent." But Verma, High and many of their colleagues have chosen to persevere despite public scrutiny and industry's chilly feet. One motivation: They are working on genetic treatments for hemophilia and they believe that this disease may well be the first to be cured by gene therapy.

For the field of gene therapy, there's a lot riding on the outcome of the hemophilia research. If there is a cure, the bloom—and the corporate investments—might come back. If it's a bust, the entire enterprise moves one step closer to a dead end. Speaking to a small group of fatigued colleagues during the annual American Society for Gene Therapy meeting last June, then-president Jim Wilson, director of Penn's Institute for Human Gene Therapy, captured the mood of the moment. "The stakes are incredibly high," Wilson said. "For once I may say what I really think: I hope to God this works."

Unflinching

KATHY HIGH'S FATHER ONCE thought she'd make a better scientist than doctor, she says, "because it was his impression that I panicked in the face of danger." That's an overstatement, High claims, and even as her colleagues down the street face an FDA-imposed shutdown, still in effect as *TR* went to press, she isn't beating a retreat. She has a couple of reasons to stand her ground. For one thing, she is using a safer gene-therapy delivery system, or "vector," than the one that killed Gelsinger. And the disease she's trying to cure—hemophilia—is more common and less complicated to treat genetically than Gelsinger's.

High works in partnership with Alameda, Calif.-based Avigen and Stanford geneticist Mark Kay, and they have plenty of competition. Two other biotech firms, Transkaryotic Therapies (TKT) of Cambridge, Mass., and Emeryville, Calif.'s Chiron, have also launched clinical trials to test their own versions of hemophilia gene therapy. At least four other biotech companies have shown interest in joining the race.

Gene therapists are looking to hemophilia as the disease whose cure will begin to justify the billions lavished on research, attract new private investment, fulfill the hype and dispel the stigma of failure. "That kind of success will have a big impact," says Joe Glorioso, director of the University of Pittsburgh's gene-therapy center, "at least in the investment community, on whether we should support this kind of biotechnology or not." Beyond redeeming the field, a cure for hemophilia would be a late but just reward for a patient population that has suffered great pain over the last 20 years.

Hemophilia is an inherited bleeding disorder that afflicts males almost exclusively. It's caused when the gene for either of two protein "clotting factors," factor VIII or factor IX, is damaged or missing. Most people with hemophilia—about 17,000 in the United States alone—treat their bleeds by injecting concentrated "factor" made from blood products or by genetic engineering. During the early 1980s, blood products contaminated with HIV decimated the hemophilia community. "Sixty percent of our families have had somebody die or have AIDS from transfused material," says New York's Mt. Sinai Medical Center hemophilia specialist Lou Aledort.

John Lanzon, a 52-year-old medical technologist in Detroit, is typical of his generation of hemophilia sufferers. Lanzon walks with a limp, the legacy of dual knee-replacement surgery, and his elbows resemble gnarled driftwood. That's because people with hemophilia do not bleed uncontrollably from cuts but instead tend to bleed into their joints, which suffer long-term damage, partly from enzymes that break down the blood. Contaminated factor gave Lanzon hepatitis B and C, as well as HIV, though he has yet to develop AIDS. Better blood-screening and heat-treatment practices, along with genetic engineering, have made today's treatments safe, but hardly ideal. "Factor will stop the bleeding," Lanzon says, "but it's not going to do a thing for the inflammation and the pain."

Because clotting factors are tremendously expensive (more than $1,000 a dose), most people with hemophilia, including Lanzon, treat themselves only after a bleed starts. Preventive treatments are a painful burden for children. Adding a good copy of the defective gene, if it works, would put a constant stream of clotting factor into the blood and eliminate bleeds altogether. Rather than just serving as a palliative, it would be a cure. "A single treatment that would keep the boys from having pain or permanent joint disability," says Children's Hospital of Philadelphia hematologist Katie Manno, the doctor in charge of administering High's experimental treatment to patients, "would be perfect."

> The outcome of the hemophilia trials could convince investors to support this kind of biotechnology—or not.

An Unlikely Crusader

AT FIRST GLANCE, HIGH SEEMS AN UNLIKELY PERSON TO BEAR THE hopes of patients and researchers for a hemophilia cure. She's a small, tidily dressed woman whose disarming friendliness and pleasant North Carolina diction make her easy to underestimate. There's not a trace of condescension in her voice—something rare in a doctor of her stature. But she's a woman of force who has made her share of enemies among colleagues and competitors. "She's straight, she says what she believes, and people don't want to hear the truth," says Lou Aledort.

High has relentlessly pursued gene therapy for hemophilia for more than a decade. In the late 1980s, when she was a junior faculty member at the University of North Carolina, her lab cloned the canine factor IX gene. After she left UNC, High continued experiments with the university's colony of hemophilic dogs. Her team's successful treatment of the dogs is one reason researchers think hemophilia gene therapy might well work in humans.

Another reason is that the new clotting factor gene would only have to find its way into a relatively small number of cells to make a difference for patients. Just 1.5 percent of the normal level

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Delivering the Goods

The baffling multiplicity of approaches to gene therapy for hemophilia (six completely different "vector," or delivery, systems are currently under study) reflects the current state of confusion in the field.

Emeryville, Calif.'s Chiron is using a retrovirus—a virus from the same family as HIV—as a vector. Since viruses normally insert their own genetic material into cells during infection they're the vectors of choice for many researchers, who remove the genes that allow the virus to replicate and cause disease and replace them with a therapeutic gene. Retroviruses in particular are an attractive option because they permanently insert genes into host chromosomes, but there's a hitch: The virus can only deliver a gene to a cell that's dividing, and the liver and spleen, where most of Chiron's vectors end up, have few dividing cells.

Though conventional wisdom says Chiron's approach shouldn't work, the company's vice president for clinical development, Bruce Scharschmidt, says that animal studies show it does. "We are absolutely confident that we saw factor VIII production in animals," he says. The University of Michigan's Randy Kaufman says the Chiron data "looks pretty weak." In animals, levels of human factor VIII fluctuated. And Chiron has yet to test the dog factor VIII gene on dogs—the definitive animal experiment. "I'm very surprised that [the FDA] allowed Chiron to go ahead with the very small amount of information they had," says Kaufman.

Frustration with retroviruses has led many gene therapists to turn to adenoviruses—a source of the common cold. Adenoviruses infect both dividing and nondividing cells, and they are astonishingly efficient at delivering foreign DNA. Unfortunately, the immune system is exquisitely sensitive to their presence, and attacks cells harboring adenovirus-delivered DNA with a vengeance. Such reactions can sometimes lead to severe illness, even death. An adenoviral vector killed Jesse Gelsinger.

Alameda, Calif.-based Avigen is working with adeno-associated virus, or AAV, a small virus that can only replicate in the presence of adenovirus or its proteins. Unlike adenovirus, AAV doesn't seem to cause disease in humans, and the immune system largely ignores it. And, at least in animals, the genes it delivers keep working for months, even years. One hemophilic dog treated with an AAV vector has been producing factor IX for almost three years.

Transkaryotic Therapies (TKT) in Cambridge, Mass., has a very different approach. Doctors at Beth Israel Deaconess Medical Center in Boston start by excising a button-sized sliver of the patient's skin. TKT scientists isolate cells called fibroblasts from the skin sample and introduce the factor VIII gene into the cells with a brief electrical pulse. The modified cells are injected into the patient's omentum, a fatty membrane in the abdominal cavity. There, in theory, they will secrete the missing clotting factor.

TKT's system sidesteps the risks of viruses, but will it work? Orthodoxy says no. Fibroblasts, in other researchers' hands, usually stop producing foreign proteins once reimplanted in the body. National Institutes of Health researcher Jay Lozier, who uses viral vectors, says: "I never would have predicted that would work." But TKT president Richard Selden says years of trial and error have allowed his company to master the approach. Time will tell if this strategy—or any of the others—can cure hemophilia.

of factor should greatly shorten bleeding episodes, and 5 percent should effectively cure. What's more, the protein only has to make it into the bloodstream, not a particular organ or tissue, to do its job.

Finally, knowing if the treatment is working—or not—won't be hard. Just take a blood sample, separate plasma from red cells, and run a simple clotting test. A big problem with other diseases that researchers have tried to treat with gene therapy, such as cystic fibrosis, is that it's almost impossible to measure accurately levels of normal protein, and improvements in symptoms might not be obvious for years. In this respect, hemophilia is easy, says High: "All we've got to do is draw blood."

Still, such a clear "readout" means failure will be obvious right along with success. And that's just one of the things that keeps High up at night. She frets, for example, over premature data leaks, and worries that reporters will get their facts wrong. She also wonders whether she should be spending more time with her three children. But as she watched a surgeon inject the first dose of her vector into a patient's thigh last June, her anxiety gave way (at least temporarily) to relief: Nothing bad happened.

Safe and Sound?

ALL THREE OF THE HUMAN HEMOPHILIA TRIALS UNDER WAY—involving 21 patients as *TR* went to press—are primarily safety trials. But intense pressure to show that gene therapy is working has prompted the companies involved to spin the best possible story. Last June, Chiron allowed *The Washington Post* to interview a patient, who told the reporter that a nosebleed ended sooner than usual. The TKT trial's principal investigator, Harvard hematologist David Roth, told *TR* that not only had none of his patients suffered significant side effects, but that "in at least one case, there appears to be a decrease in spontaneous bleeding." Still, Roth stressed that it was too early to draw conclusions.

Avigen made the biggest splash. A December press release announced that the first three patients had "factor IX activity" and needed fewer injectable doses of factor than they had before the trial. Mt. Sinai Medical Center's Aledort saw the data in early December. Though guardedly enthusiastic, he found the results to be far from conclusive. "I think it's much too early to say this is the answer," he says. One patient, for example, had indeed generated a "therapeutic" level of factor IX—but that level subsequently dropped. As for patients needing less factor after the treatment, "the question is, is this a placebo effect, or is it real?" says Aledort. "How the hell does anybody know that yet?" The jury will be out for a while. "If you really went a year, even six months, with consistent levels [of factor], I would say it's working," says Aledort.

And even though there weren't obvious ill effects in the first six months of treatment, that doesn't mean there won't ever be any. One of the biggest dangers is that of inhibitory antibodies, or "inhibitors." The very word fills hemophilia sufferers with dread. Overall, about 20 percent will, at some point, develop inhibitors that prevent factor from working. Massive doses of factor can often overcome these antibodies, but people with inhibitors tend to suffer more and die earlier than those without. Because of the hemorrhage risk, "surgery becomes impossible," says Aledort, and "trauma leads to death not infrequently."

Although only about 3 percent of patients with hemophilia B—the less common of the two forms of the disease and the one

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High is working on—develop inhibitors, they run a special risk when they do. Some of them suffer a life-threatening allergic reaction to factor, and giving more factor can lead to kidney failure and death. "They're almost untreatable," says Aledort. "It's a very big deal."

Because no one knows whether gene therapy will be more or less likely to cause inhibitors than conventional factor therapy, some experts think all the current trials are premature and dangerous. It's possible that gene therapy could give rise to inhibitors in people who never had them before, making any treatment difficult or impossible, and putting lives at risk. "I would like to see a more cautious approach," says University of Michigan protein biologist Randy Kaufman, who helped clone the gene for factor VIII in 1984. Kaufman believes all three companies should have shown they can overcome inhibitors in mice and dogs before experimenting on humans. "I know that if I had a son [with hemophilia]," he says, "I would not want him to go into a clinical study today."

The companies strongly defend the timing of the trials. And High, for her part, bristles at the suggestion that she should have waited to complete animal studies on inhibitors before trying gene therapy on humans. "We've been using protein concentrates for [30] years," she remarks, "and we still don't know how to predict, in that setting, who's going to get an inhibitor." High doesn't flinch from the hard reality that medical experiments like this must ultimately be performed on people. "No matter how many experiments you do, there's only a certain amount you're going to learn about the immune response in humans by studying mice," she says. "Sooner or later, you have to try and answer questions in the species you really want to work on."

Not that High is rushing in blindly. She points out that her approach, using a small virus to deliver the normal factor IX gene *(see "Delivering the Goods," p. 60)* has worked in culture, in mice and in dogs—and seems safe. The animal data that does exist on inhibitors is reassuring. (Only one dog developed them, and they disappeared within a few months.) Meanwhile, her lab is putting a lot of effort into creating transgenic mice with the same genetic mutations found in humans in order to test inhibitor formation, and treat it. But she isn't waiting on those results before trying gene therapy on people.

Cure or Catastrophe?

BY MID-SUMMER, HIGH'S TRIAL AND THE CHIRON TRIAL SHOULD be complete. (TKT plans to finish by the end of the year.) Results are keenly awaited. As Jim Wilson told hemophilia researchers at the June American Society for Gene Therapy meeting: "The world is watching what you guys are doing, and what's happening in the clinical trials."

A cure for hemophilia could galvanize gene therapy. "It would be a tremendous boost to the field, particularly in view of the negative events that have happened recently," says University of Michigan researcher Jeff Chamberlain, who's working on Duchenne muscular dystrophy. Not only would the achievement bolster morale, Chamberlain says, it could also attract bright researchers to the field and help promote the technology across the whole spectrum of diseases. Industry analysts agree. "This would be one of the first steps towards validating gene therapy as a treatment protocol," says Anthony Shimkin of Wedbush Morgan Securities in Los Angeles. But the flip side of the scenario is that failure in hemophilia—given all the disease's advantages—could shake confidence in gene therapy even further. "It would be a huge problem," says biotech analyst Al Rauch of First Union Securities in Chicago, "because you can't really think of a good reason it wouldn't work." Disappointment in hemophilia, Rauch says, "would indicate people have very little understanding of how [gene therapy] works."

Might that stall the entire field? "I think it's a possibility," says Shimkin. But he's quick to stress that gene therapy will survive regardless of the outcome of the hemophilia trials: "It won't be so much a case of, 'gene therapy's not here to stay,' as 'let's go back to the drawing board.'"

Gene therapy's success or failure in hemophilia could be known in a few months, but some questions won't be answered for years. Will the new gene, randomly lodged in a cell's chromosome, trigger cancer? Will it make its way into germ cells (sperm, in this case) and get passed on to children? That could be catastrophic, since *every cell in the body* would inherit the foreign gene. Normally, cells selectively repress the expression of many genes, keeping them dormant, but the new gene, because of the way it's engineered, would be turned on everywhere. Such hyperactivity could be "devastating" to a developing fetus, says gene-therapy researcher Jon Gordon of Mt. Sinai Medical Center.

Some patients feel better, but is it just a placebo effect? Lou Aledort asks: "How the hell does anybody know that yet?"

Most researchers working with viral vectors consider these risks minimal. (High's lab found that Avigen's vector makes it into the testes of rabbits, but not their sperm.) Still, Jesse Gelsinger's shocking death showed how a vector commonly considered safe could deliver an ugly surprise. "We are not very sophisticated, yet, in really controlling what we're doing when we give these vectors," says Gordon. "Their biological distribution, their fate, and how they behave *in vivo*—we have a lot of knowledge that's yet to be acquired there."

By the end of the year, when the last of these trials should wrap up, over 30 hemophilic patients will have exposed themselves to largely unknown risks. "They're really pretty brave," says Kathy High. Safety aside, will gene therapy work? High is confident hers will, especially at the higher doses planned for the end of the trial. But what if inhibitors develop—or worse? "If there was a death in a hemophiliac, that would set the field back a decade," says University of North Carolina hematologist Gilbert White.

High, as always, remains alert for any sign of trouble—even in the fortune cookies that come with the Chinese dinners she likes to order. A recent one seemed ominous: "When things are going well is the time to prepare for danger." ◊

Intellectual Property Evaluation is a daunting challenge using today's traditional methods of reading, sorting, and key word indexing. Nonetheless, it is an essential requirement for companies to "discover what they know." Their intellectual property (IP) can be leveraged for new product designs, while avoiding the "re-inventing the wheel syndrome." Furthermore IP often serves **an additional revenue stream**, as a few larger companies have made IP licensing a **billion dollar** per year **contribution** to their bottom line. Without truly knowing the content of your intellectual property, you are at risk of missing your chance to exceed your revenue goals.

Traditional Approach Falls Short

The first steps typically taken involve document management tools, which help to organize documents by titles and by indexed key words. There have also been some tools developed to extract key words using statistical methods. This may appear to be a good start, but ultimately companies need the ability to automatically extract and organize all the key concepts within their entire intellectual property portfolio. Since this information is doubling every seven months, the automation is very critical to success.

Automated IP Evaluation

A recent breakthrough in semantic processing technology holds the key. Invention Machine Corporation, a Boston-based software company, has developed such a technology, and recently released CoBrain™ the knowledge processor to address the needs of **Information Technology** (IT) **and Knowledge Managers. CoBrain reads** on-line documents, **extracts** all key concepts, and **automatically creates** a knowledge index in a **problem-solution format,** which is optimized for sharing as an Intranet or Internet portal. The problem-solution format is ideally suited to the R&D community as they are looking to find solutions to their tasks at hand. For example, an engineer or scientist will search their Intranet repositories or the Internet for ways to reduce friction or deposit thin film, and all too often thousands of items are listed. Now it takes hours or even days to wade through this information to find any relevant knowledge. Because CoBrain has an understanding of words, contexts, and relationships, the multi-pass reasoning and semantic algorithms will extract all key concepts and create a problem-solution index. Now, R&D can quickly have a clear understanding of their IP, and be able leverage it more quickly. The knowledge index also **promotes the company's value** prior to an acquisition, or on the other hand, helps to better understand what will be acquired. Now that a company can get an understanding of its intellectual property, it can begin to determine which IP can be licensed and turned into *intellectual assets.* -

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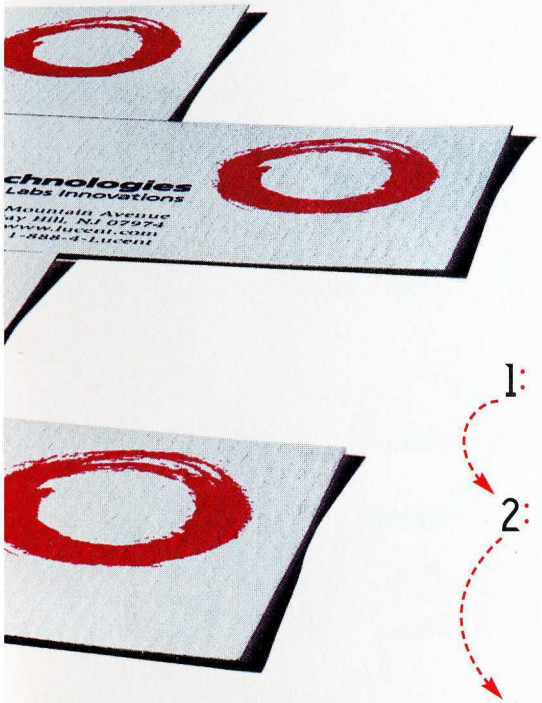

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IP WATCH

Software Patents Tangle the Web

A profusion of new software patents on Internet business methods puts our notions of intellectual property to the biggest test yet.

BY SETH SHULMAN

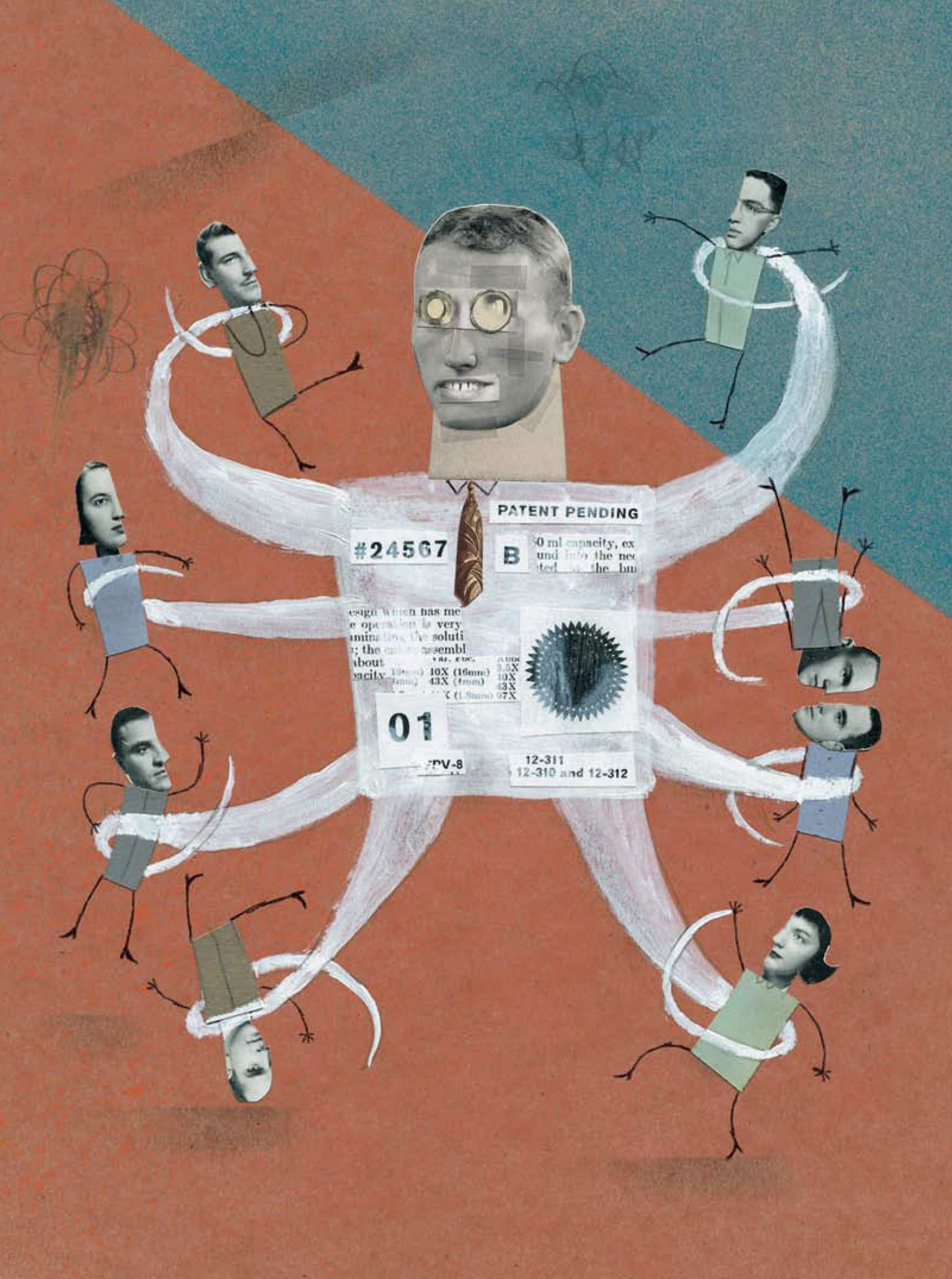
HERE'S A NATURAL IDEA FOR AN E-BUSINESS: an "experts online" Web site. With a team of specialists willing to answer queries over the Web and a garden-variety search engine to pair these authorities with advice seekers, you could have an Internet business up and running in no time, fielding questions on everything from accounting to xerography. To make the site really slick, you could let users select the credentials they want in their experts and the fee they are willing to pay.

But before you tap your savings there is something you should know: This business has been patented.

Sounds hard to believe, but last year the U.S. Patent and Trademark Office (PTO) granted exclusive rights to this "invention" to multibillionaire entrepreneur Jay Walker and his Stamford, Conn.-based intellectual property firm, Walker Digital. U.S. Patent No. 5,862,223 ("Method and apparatus for a cryptographically-assisted commercial network system designed to facilitate and support expert-based commerce") contains more than 200 separate claims that spell out—in the broadest possible terms—the idea of dispensing expertise via the Internet.

To outsiders unfamiliar with the latest developments in the through-the-looking-glass world of intellectual property claims, Walker's patent might seem absurdly broad. But broad patents on software-enabled businesses are fast becoming commonplace, especially in the burgeoning field of e-commerce. According to Q. Todd Dickinson, commissioner of the Patent Office, which is a division of the U.S. Department of Commerce, his agency is now receiving over 2,500 applications per year for so-called "business method

ILLUSTRATIONS BY DAVID PLUNKERT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"The Patent Office is issuing patents for blindingly obvious things." —Law professor James Boyle

software" patents.

To get a patent—whether for a new type of toothbrush or an energy-saving light bulb—an invention has to be "novel," "useful" and "non-obvious" to an expert in the field. And as Dickinson explained recently to *TR*, the PTO views ownership claims on business methods like Walker's as "actual, describable, discrete inventions" that meet these time-honored criteria.

Although Dickinson makes the new patents sound like business as usual, the fact is that the patent system has recently moved deep into unmapped terrain. A series of U.S. court decisions over the past several years, culminating in an influential 1998 ruling, has flung the doors wide open to patent claims on all manner of software-mediated business concepts, from online insurance policies to electronic voting.

Most of these new ownership claims have yet to be tested in the courts, but the number of high-profile disputes is mounting. In one closely watched case, a court injunction at the end of 1999 forced the online bookseller Barnes & Noble to remove from its Web site the feature that allows cybershoppers to buy books with one click of their mouse. The reason? Amazon.com's exclusive patent on the so-called "1-Click" purchasing method.

With billions of dollars in Internet sales at stake, the proliferation of broad e-commerce patents is sowing confusion, uncertainty and a good deal of cynicism among many software developers and business leaders. Some legal experts, such as Robert Merges, a law professor at the University of California, Berkeley, believe the sheer number of patents now pending on business methods has "pushed the patent system into crisis."

Others claim that a system designed to protect innovation is being turned into a weapon for crushing competitors. As law professor James Boyle of American University in Washington, D.C., puts it, "The Patent Office is issuing patents for blindingly obvious things just because they are being done with software or on the Internet." Boyle says the patents are already causing "a chilling effect on electronic commerce."

Edison 2.0

IT WILL BE YEARS BEFORE THE ULTIMATE winners and losers emerge from this growing thicket of intellectual property claims. But one thing is clear: e-commerce patents are pulling in capital as surely as an electromagnet attracts scrap metal. No one better embodies the current trends than Jay Walker himself, a man who was compared recently to Thomas Edison on the cover of *Forbes* magazine. With a nod to his illustrious forebear, Walker likes to call his firm, Walker Digital, an "idea factory." But it operates far differently than Edison's outfit ever did. Fully a third of Walker's 60 employees staff its legal department: electronic scribes who spin out an average of two highly conceptual patent applications every week.

One of these patents—governing "buyer-driven sales" over the Internet—led to Priceline.com, a Web site begun as a means to allow consumers to bid for unused seats on airplanes and now scrambling to broaden its offerings to include everything from hotel rooms to groceries. The company, like so many Internet startups, has never turned a profit. But this hasn't stopped investors from driving Priceline's stock market value north of $10 billion, with Walker himself amassing a staggering paper fortune in the process. And much of this enormous windfall owes to the 20-year, government-sanctioned monopoly that Walker's patent provides on Priceline.com's core business method: using the Internet to let buyers name the price they're ready to pay, and letting sellers decide whether or not to meet it.

If Priceline.com's ability to attract investment is any measure, Walker Digital's formula is working, and the firm has hundreds more patents in the works. Yet many of these are certain to raise eyebrows, like the one that describes the invention of ordering fast food from your Palm Pilot before arriving at the drive-up window. According to Boyle, even if you accept the notion of patenting business methods, some ideas are just "far too obvious" to merit a patent. By allowing Walker and others to own these ideas, he says, "the Patent Office is creating a ridiculous situation." Not surprisingly, Dean Alderucci, head legal counsel for Walker Digital, concurs with PTO commissioner Dickinson that these kinds of ownership claims represent "a very logical extension of the patent system" we have always had. "If you have a new and useful business method," Alderucci says, a patent can "force the money out of it and benefit the public."

While Walker may excel at the game, his is not the only company with a strategy at the Patent Office *(see "Will Patents Rule Commerce on the Net?" p. 74)*. The firm CyberGold, for instance, has patented the idea of using incentives to reward consumers for paying attention to Internet ads. Open Market, a Massachusetts-based startup whose motto is "The Future of Business," now owns three patents that are arguably indispensable to conducting e-commerce. One, U.S. Patent No. 5,724,424 lays claim to methods for making secure credit card payments over the Net. And Patent No. 5,715,314, covers the notion of electronic shopping carts, a system used by many e-commerce Web sites to let shoppers mark items for later purchase. The list goes on and on.

Broad and Broader

COMPANIES SUCH AS WALKER DIGITAL have been emboldened to seek e-commerce patents—and to enforce them—thanks to a critical 1998 U.S. Appeals Court decision. In the case, California-based Signature Financial Group and Boston's State Street Bank went to court over a method of calculating the value of a customer's share of multiple mutual funds. Signature claimed its patent gave it exclusive rights to this classic computer accounting system, known as the "hub and spoke" method, which is used widely by banks around the world.

State Street's lawyers argued that neither mathematical algorithms nor business methods were patentable. The law had long been murky on both these issues, and in

the initial decision a judge ruled in State Street's favor, agreeing that Signature's computerized business method didn't deserve the same patent protection given to other types of inventions. On appeal, however, the higher court firmly upheld Signature's claims, giving an unequivocal green light to patenting software-enabled business practices. According to Alan Fisch, an intellectual property attorney with Howrey Simon Arnold & White in Washington, D.C., the "State Street" decision marks nothing less than "the endpoint of a nearly 30-year line of debate over what is patentable in this field."

Less than a generation ago, in the early days of the computer age, the PTO simply refused to grant patents on software. The reasoning then was that software code is made up of strings of instructions, something like the recipes in a cookbook. And historically, the U.S. legal system has treated instruction sets as forms of expression protected by copyright law—not patents.

The distinction is far from trivial because copyright, by protecting a whole work and not its individual parts, allows practitioners far more latitude. Thus, a symphony may be copyrighted, but musical notes, phrasings, and motifs are kept in the public domain, so that they can be used in other pieces of music. Likewise, the PTO's traditional thinking was that basic software algorithms should be freely available to all programmers. As co-creator of the Linux/GNU operating system and "open source" software advocate Richard Stallman notes, "A decade ago, the field of software functioned without patents. It produced innovations such as Windows, virtual reality, spreadsheets and networks. And because of the absence of patents, programmers could develop software using these innovations."

Early on, the courts tended to agree with this view, as in a 1972 Supreme Court ruling that compared software's logical steps to "mental processes" that not only couldn't be patented, but had to be preserved in the public domain as the "basic tools of scientific and technological work." Over time, though, this position began to erode. In the landmark 1981 case *Diamond* vs. *Diehr,* the Supreme Court upheld a patent on a rubber-making machine controlled by software. Here the logic was that software had altered the machine's functioning so significantly that it had effectively created an entirely new, and eminently patentable, invention.

The precedent established by *Diamond* vs. *Diehr* left the door to software patents slightly ajar, and it wasn't long before a flood of applications came rushing in. By the early 1990s, software had become one of the fastest growing sectors of the U.S. patent system. By one estimate, the PTO, which had once categorically rejected the idea of patenting software, will have granted close to 100,000 software patents by the end of this year.

From the outset, software patents posed serious problems, as programmers realized that they were technically violating patents when they developed programs that generated footnotes (U.S. Patent No. 4,648,067) or compared documents (Patent No. 4,807,182), to name just two. By approving patents on widely used subroutines, many felt the PTO was endangering the entire software industry. The situation led Mitch Kapor, founder of Lotus Corp. and now a principal of cyberspace think-tank The Electronic Frontier Foundation, to predict in 1991 an impending meltdown in the industry because of proliferating lawsuits. He warned of a "Bhopal of software patents," referring to the world's most deadly industrial disaster that struck the Union Carbide plant in Bhopal, India, in 1984.

Yet so far at least, the effects of software patents have not been nearly so dire as predicted. Eugene R. Quinn, Jr., a law professor at Barry University School of Law in Florida, has tracked the number of patent lawsuits over the past decade. While he has found a significant rise in the number of lawsuits filed, he also notes that the number of full-blown trials has so far held steady. "A lot of cross-licensing is going on, especially in the software field," Quinn says, "because many of the patents out there are invalid." Some legal scholars liken the situation to a commercial equivalent of MAD (mutually assured destruction) in which patents act as powerful deter-

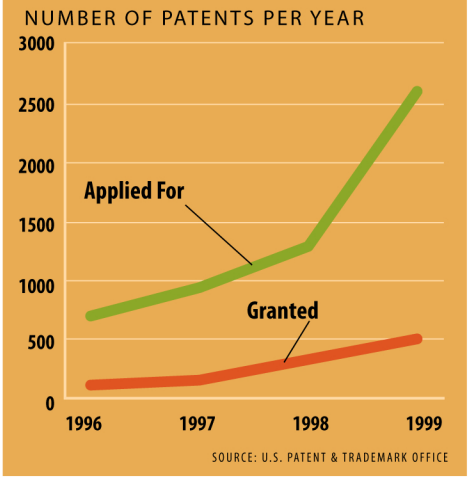
rents to attack but can't actually be used. Another restraint is the high cost of going to trial, which the American Intellectual Property Law Association puts at over $1.2 million even for simple patent disputes. Although the situation clearly favors bigger firms, Quinn says, there is a good deal of fear among all parties, and incentives to co-operate are high.

Clouds Over Crystal City

JUST BECAUSE SOFTWARE HASN'T EXPERIenced a cyber-Bhopal doesn't mean it won't ever happen. Indeed, the noxious clouds of litigation now gathering around e-commerce are renewing industry fears. What's more, in what lawyers are calling the "post-State Street environment," all bets are off for a software *détente* as companies are not just patenting specific algorithms, but far more valuable Internet business concepts. And to the great dismay of critics who fear a wave of crippling lawsuits, the PTO may be granting many of these software patents in error, simply because it can't keep current with advances in the field.

e-Patents Rising

Patents on computer-related business methods are increasing. Bolstered by a 1998 legal decision, new applications for such patents have leapt dramatically.



SOURCE: U.S. PATENT & TRADEMARK OFFICE

By law, no invention can be patented that has already been patented by someone else or has been published prior to the time the patent is filed; in the language of the legal system, such patents and publications are known as "prior art." A key problem is that software programming—especially in its early days—was famous for its lack of a published paper trail and for the informal exchange of code and techniques among programmers. These poor "non-patent" records, combined with the PTO's late arrival to the software game, mean the agency examiners who scrutinize applications often have tremendous difficulty establishing exactly when an invention was first made.

"The prior art problem is one issue where software patent proponents and opponents typically find common ground," says Alan Fisch, who in 1994 was one of the first computer scientists hired by the PTO to work on software patents. Although the PTO has hired hundreds of new software examiners since then, Fisch says that, despite the agency's best efforts, "the corpus of existing software patents does not define the totality of software innovation." In other words, the PTO's collection of software art still resembles the tip of the computer science knowledge iceberg. Although the PTO boasts that examiners have access to some 900 online databases, the reality is that, by almost all accounts, prior art searches in the software field sorely test the PTO's capabilities.

The best-known example of the PTO's mishandling of prior art came in 1993 when the California-based firm Compton's New Media, creator of an early multimedia CD-ROM titled Compton's Interactive Encyclopedia, announced that it had received a patent on multimedia itself—specifically, the "process and concept" of retrieval technology in multimedia databases. With scores of multimedia CD-ROMs already on store shelves, the announcement was a bombshell.

The patent seemed ridiculous, not least because techniques for indexing and searching multimedia databases had been explored at Xerox's Palo Alto Research Center almost two decades earlier. Under pressure from the software industry, Bruce Lehman, then-commissioner of the PTO (Dickinson's immediate predecessor), took the highly unusual step of second-guessing his own examiners. He called on the Patent Office to re-examine the patent, this time taking into account "new evidence" that had come to light—namely, the prior art the agency had missed the first time around. The result: Every one of Compton's 41 claims were rejected.

Over the past decade many have tried to redress the prior-art problem. One group of programmers, led by Bernard Galler, now professor emeritus of electrical engineering at the University of Michigan, founded a venture in 1992 called the Software Patent Institute. The idea was to have programmers voluntarily submit a pool of information about existing know-how that the U.S. Patent Office could use in its search for prior art. While the PTO's ability to detect spurious patent claims has improved through such undertakings, Galler admits the effort has met with only limited success and that there is still far to go.

Just how far remains an open question. One of the Patent Office's harshest critics, Greg Aharonian, publishes the Internet Patent News Service and makes his living investigating the validity of software patents on behalf of firms involved in lawsuits. Aharonian claims that half to 70 percent of the software patents issued can't pass what he calls "the Crystal City test." That is to say, if U.S. patent examiners ventured beyond the walls of their headquarters in Crystal City, Va., they would find that the techniques they are patenting are already widely known and used among programmers.

"The Patent Office is doing a horrendous job in the software area," Aharonian contends bluntly, "and they have made zero progress since the Compton's New Media patent in handling non-patent prior art." In a 1999 survey, Aharonian found that half of all patent applications surveyed cited no prior art at all. The result, he believes, is a disaster in the making. "No matter how bogus they may seem, patents can be powerful weapons," Aharonian says. "As people start making money on the Internet, you can fully expect these patents to start being asserted."

Software Showdown

IN ONE EMERGING BATTLE TO WATCH, Microsoft announced last fall that it would let consumers name their price for hotel rooms on its travel Web site Expedia. As expected, Priceline.com has now sued Microsoft and its Expedia subsidiary, claiming infringement of its patent on buyer-driven commerce. Industry observers say Priceline.com had little choice but to sue, since to have done otherwise would have welcomed more competitors

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"We are going to do the best job we can, just as we have with every technology that has blown onto the scene." — PTO Commissioner Q. Todd Dickinson

and been an admission that its patent might not hold up in court.

Although neither side would comment on the specifics of the case, Priceline.com may have a considerably more difficult time proving its patent is "novel," "useful" and "non-obvious" in court than it had at the Patent Office. For one, the patent could be invalidated if Microsoft successfully produces a single piece of evidence of prior art. Expressing confidence in his firm's patents, Walker Digital's Alderucci says the company takes great pains to research prior art with an eye to possible lawsuits. "Any patentee has to consider the chance of litigation," Alderucci says. "We have anticipated it and are very well prepared for it."

Even without a prior art knockout, the case could raise the $64 billion question of whether applying Internet technology to facilitate buyer-driven sales is an "obvious" use of the technology. And Priceline's investors may not like the answer, especially since juries tend to take a more commonsense approach to the question of what is obvious than the PTO has. In 1997, for instance, the software firm Quantel sued San Jose, Calif.-based Adobe Systems for $138 million claiming that Adobe's popular Photoshop software infringed five of Quantel's patents covering painting with a stylus on a computer. The jury sided with Adobe, in an outcome widely seen as highlighting the difficulty of enforcing questionable patent claims on competitors.

Whatever their outcome, the Priceline.com dispute, as well as Amazon.com's ongoing tussle with Barnes & Noble, are likely to set important precedents. If the e-commerce patents stand up, it will certainly precipitate even more patenting of business processes, more litigation and potentially a backlash led by large online firms increasingly hit by debilitating infringement suits. Losses by Priceline.com and Amazon.com could mean fewer companies enforcing e-commerce patents, although in no case is the patenting likely to stop, as the business claims will continue to prove useful for attracting investors and for cross-licensing.

Toasters or Tollbooths?

FOR HIS PART, PTO COMMISSIONER DICKINSON says he too is curious to see whether the business methods patents will hold up in court. For now, he is confident that Wall Street wouldn't be making the investment if the patents weren't strong. Nonetheless, Dickinson notes that the courts always function as a check on the job the Patent Office is doing. As he puts it, "We are going to do the best job we can, just as we have with every technology that has blown onto the scene. If the courts tell us we need to make an adjustment, we don't mind that a bit."

Taking a long historical view, much of the current patent conundrum stems from the advent of a new and uncharted technological realm. The Patent Office has almost always had problems with dramatic technology shifts, and software and the Internet are no exceptions. In the highly legalistic and precedent-driven view of the patent system, the lack of clearly defined "prior art" in emerging technological environments makes almost anything seem like fair game for an ownership claim.

PTO commissioner Dickinson likens the situation to the advent of electricity. "Man was making toast for thousands of years before electricity came along," Dickinson says. "But electricity opened the door for inventors to claim new methods for using a coiled wire of certain resistance to control the toasting of bread."

The idea of patenting toasters seems reasonable enough, but unfortunately, Dickinson's analogy falls short in the current climate. Put simply, the business method patents now being granted for e-commerce seem more akin to patents on the *idea* of toasting bread. The problem, critics say, is that the system is supposed to provide incentives to invent new toaster designs. But if someone owns the idea of making toast—or even the idea of making toast with electricity—the claim

Will Patents Rule Commerce on the Net?

A selection of broad e-commerce patents issued by the U.S. Patent and Trademark Office.

COMPANY	U.S. PATENT NUMBER	SUBJECT	UPDATE
Amazon.com	5,960,411	one-click purchasing	Amazon.com has used its patent to force changes to Barnes & Noble's Web site.
CyberGold	5,794,210	attention brokerage	Patent covers rewarding Web surfers for paying attention to online advertisements.
E-Data	4,528,643	download-based sales	A judge blocked E-data's attempts to enforce this pre-Internet era patent.
Netcentives	5,774,870	online incentives	One of several recently issued patents covering reward systems for Internet purchasing.
Open Market	5,715,314	electronic shopping carts	This patent may be infringed by many e-commerce sites on the Internet.
Priceline.com	5,794,207	buyer-driven sales	Priceline has sued Microsoft and its Expedia travel site for copying its patented business method.
Sightsound.com	5,191,573	music downloads	Sightsound is demanding a 1% royalty from all online music sellers, and has sued Time Warner's CDNow.com music site for infringing its patent.

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"No matter how bogus they may seem, patents can be powerful weapons." — **Patent buster Greg Aharonian**

will clearly deter the emergence of new and varied toaster designs. Instead it will function like a needless tollbooth assessing royalty fees on everyone in an industry, or worse, like a roadblock that deters would-be competitors.

There's ample historical evidence that overly broad patents have stifled innovation in emerging industries. A century ago, Henry Ford was held for ransom by George Selden's "road engine" patent, granted to Selden even though he had never constructed an automobile. Ford prevailed in the courts, but only after a costly legal battle. In the early years of aviation in the United States, Orville and Wilbur Wright fought a largely successful nine-year campaign to enforce their broad patent on the airplane. While innovators helped aviation thrive in Europe, the Wright brothers' patent crippled American industry until the outbreak of World War I, when the U.S. government forced the Wrights to license their technology so that planes could be built more expeditiously for the war effort.

To some, like Raymond Van Dyke, a patent attorney with the Dallas, Texas-based law firm Jenkens & Gilchrist, these and other examples are proof that the patent system is ultimately self-correcting. Historically, he says, "when there has been enough perceived inequity in the patent system, industry has revolted and other mechanisms have kicked in." In the case of e-commerce patents, Van Dyke predicts "the courts will probably step in. Congress may have to step in. But you have to remember that all these forces, including broad societal forces, come together in a confluence that creates the law."

In that view, it might behoove us all to park our electronic shopping carts for a moment and try to remember what the patent system is for—and what it's not. The U.S. Supreme Court ruled wisely on the matter in a verdict issued more than 100 years ago. In the case, the court wrestled with the question of when a minor improvement—in this instance to a boat propeller—rose to the level of a *bona fide* new invention. The decision resonates with uncanny prescience throughout the current debate:

> It was never the object of patent laws to grant a monopoly for every trifling device, every shadow of a shade of an idea, which would naturally and spontaneously occur to any skilled mechanic or operator in the ordinary progress of manufactures. Such an indiscriminate creation of exclusive privileges tends rather to obstruct than to stimulate invention. It creates a class of speculative schemers who make it their business to watch the advancing wave of improvement, and gather its foam in the form of patented monopolies, which enable them to lay a heavy tax on the industry of the country, without contributing anything to the real advancement of the arts. It embarrasses the honest pursuit of business with fears and apprehensions of unknown liability lawsuits and vexatious accounting for profits made in good faith.
>
> —U.S. Supreme Court, *Atlantic Works* vs. *Brady,* 1882

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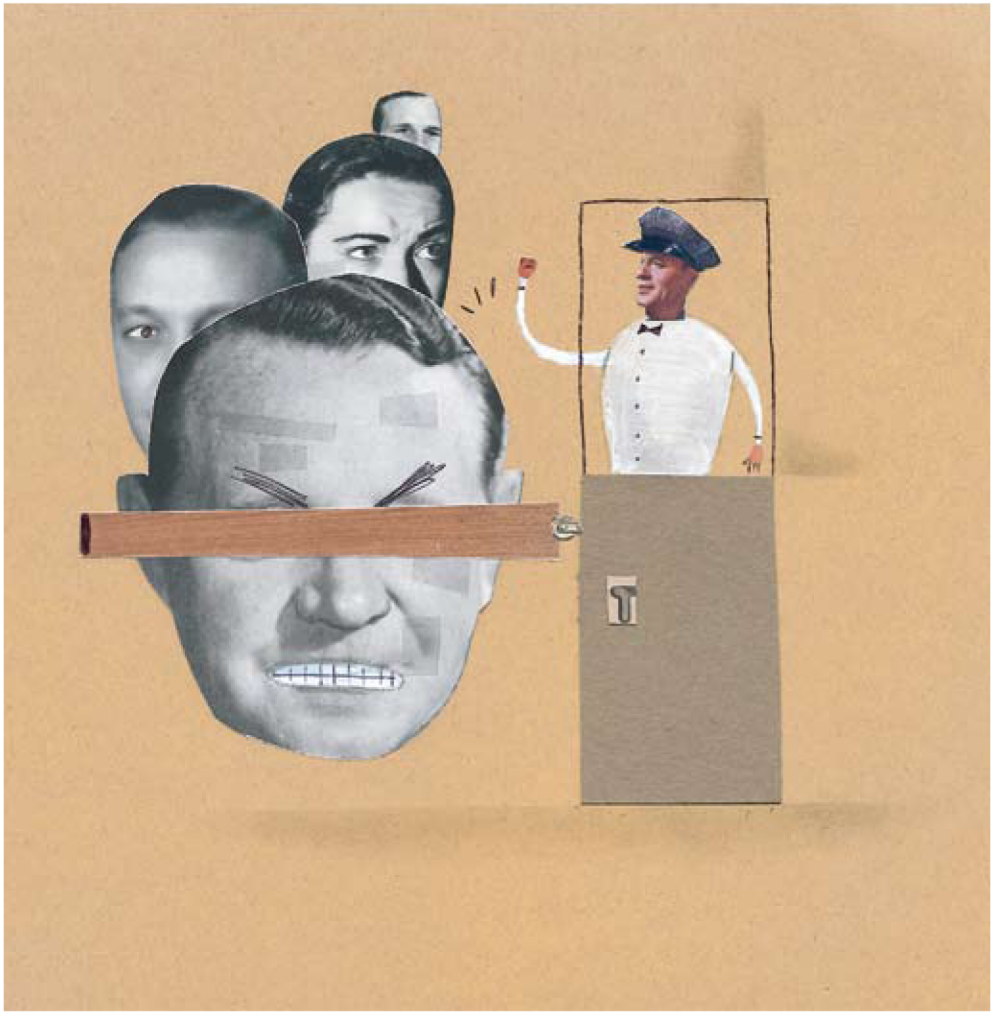

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The Value of Content

IP WATCH

ONCE UPON A TIME, ARTISTS HAD AN EASY LIFE. When dancers and singers performed, only people in the immediate vicinity could enjoy the show, and they could be asked to pay up. Then over the centuries came technology—storage, reproduction and transmission—and along with it, the artist's ever-growing reliance on technological intermediaries, who in turn have relied on government protections. Printing presses meant that books could be reprinted by others and revenues lost (hence Queen Anne's Copyright Act of 1709). Broadcast meant works could be copied by consumers (hence the European levy on VCRs and blank cassettes).

The last wave of technology may be the most challenging of all. Digital recording is immune from the degradation that plagues analog recording devices: The millionth digital copy is exactly the same as the first. The Internet means a music file can be sent to millions of e-mail addresses with the stroke of a key. My role in this arena began in 1988 when I founded MPEG, the Moving Picture Experts Group (www.cselt.it/mpeg), a committee of the International Organization for Standardization. The MPEG-1 standard, approved in 1992, enables storage of compressed digital video and audio on compact discs; it is the technology behind MP3, a standard used by millions of enthusiasts to compress CD music files and move them over the Internet.

MP3 is great because it overcomes the clumsy traditional way of distributing content based on the sale of a physical object such as a vinyl record or CD. But it has also caused problems—since piracy of music is now widespread on the Internet. Some people justify their actions with a philosophy that holds, "Bits are bits, content should be free." But, if that is true, how can an artist earn a living? Simple, they say, if music is free it can be used as a vehicle for a message that does have monetary value. But if I were an artist, I would rather live a dignified and penniless life than see my genius used to advertise the footwear of Acme Shoe Manufacturing Co. (Don't count on my resolve, though. Under the pangs of hunger I might eventually accept it.)

That is why protection technologies applied to digital content are destined to play such an important role in the future of our networked society. When content can no longer be indiscriminately copied, it recovers its lost value. And instead of being the cause of its devaluation, the Internet becomes the place where content's value is enhanced because everybody can post works in a protected form and be compensated for them. Artists will have a better way to reach their fans, and consumers will be able to acquire the right to consume a piece of work in more ways than it is possible today: Instead of buying a CD, for instance, a consumer might buy the right to 10 playbacks.

This is the reason why, a year ago, I agreed to lead the Secure Digital Music Initiative (www.sdmi.org), a nonprofit organization with 150 corporate members whose shared goal is to develop specifications for secure digital music. So far, SDMI has produced a specification for portable devices that play digital music in a secure form.

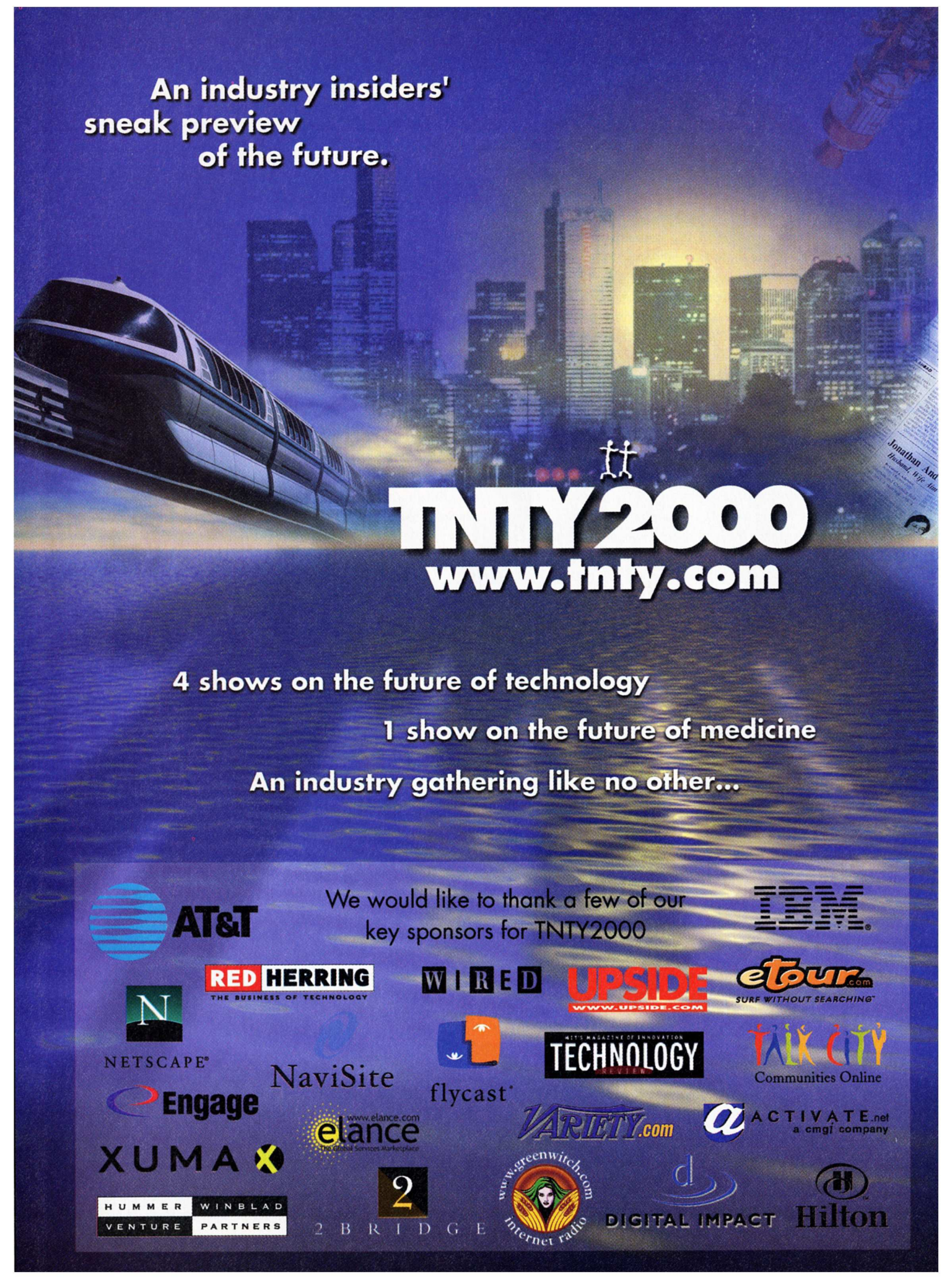
However, more technologies are needed for a reliable market in digital music to emerge. One is OPIMA's (www.iec.ch/opima) specification for the secure download of proprietary protection systems that will enable Web surfers to consume whatever type of protected content they may encounter.

But in a world where every Netizen can be author, performer, producer, value-added reseller and consumer all in one, how will it be possible to acquire the rights for a specific work, possibly worth a few cents, for reuse under some given conditions, unless all these negotiations and transactions are rendered automatic? Fortunately, an answer is beginning to be provided by the Foundation for Intelligent Physical Agents (www.fipa.org), whose Agent Communication Language defines a *lingua franca* that all intelligent agents will speak, and by MPEG-7, a standard due to be completed by July 2001, with which it will be possible to give semantic descriptions of audio and video objects. What happens when these technologies are combined? Imagine sending your intelligent agent searching for a picture of a lady on the seashore with a background of palm trees, and negotiating a price for it of no more than 50 cents.

Protection technologies applied to digital content will play an important role in the future of our networked society.

Putting these technologies together is no simple task, because each has been developed by different industry groups driven by their own models of the world. This is why MPEG has recently begun developing a new standard called "MPEG-21 Multimedia Framework," which will integrate two critical objectives: how consumers can search for and get content—directly by themselves or through the use of intelligent agents—and how content can be decoded for consumption according to usage rights. The standards underpinning the MPEG-21 goals are of such importance for enabling this new paradigm as the Web evolves to the broadband of tomorrow, that I am sure no company with a stake in this transition can afford not to be part of this effort. ◊

Leonardo Chiariglione is head of multimedia technologies and services at CSELT, Telecom Italia's R&D center in Torino, Italy.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IP WATCH

Companies Squeeze the Patent Pipeline

BY ROBERT BUDERI

The *Technology Review* Patent Scorecard shows corporations focusing more than ever on intellectual property—but with sharply contrasting strategies.

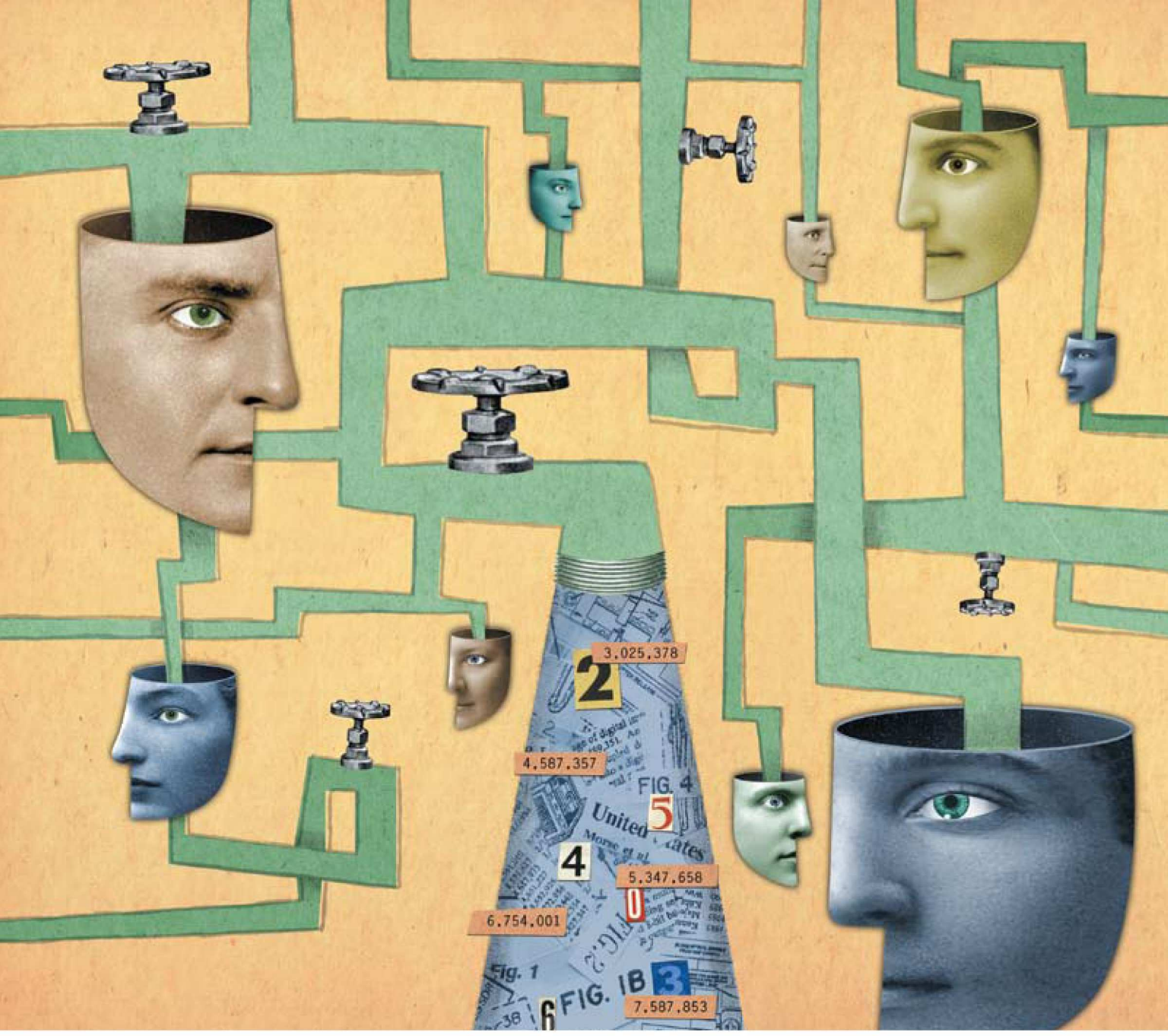
AT&T BOSS MIKE ARMSTRONG HAS A LOT of cards on the table. Witness his forays into cable television, local phone service and Internet access. To support these bold initiatives, a few years ago Armstrong ordered his researchers to bulk up AT&T's intellectual property position, a strategy that has sparked an almost sevenfold increase in the number of patents issued in 1999 versus just two years earlier.

Now look at 3M—the inventor of Post-it notes and Scotch tape—whose name is almost synonymous with corporate creativity. There, 1999 patent output fell by nearly 150, a 24 percent dropoff from the previous year.

It might seem that one of these longtime research leaders suddenly hired a bunch of brilliant inventors while the other has forsaken R&D. Hardly. In fact, the two are aggressively pursuing the same goal: innovation. In AT&T's case, the company is storming into some white-hot and rapidly changing areas—so its braintrust upped the ante on patenting. Explains intellectual property and standards vice president Jeff George, "We want to build picket fences around the technologies that we think are most important for the future."

3M is also striving to "fence off" vital technology areas. Part of that effort, though, is a push to *reduce* filings extraneous to 3M's businesses—a strategy that can diminish total patent output but if done right improves the payoff from a company's inventions. Indeed, officials cite a 25 percent rise in the number of new products introduced in 1999. Patenting remains central to 3M, says senior vice president for research and development Bill Coyne, citing a legal change a few years back that spurred a rash of filings responsible for much of 1998's all-time high of 617 patents. But while he expects the num-

ILLUSTRATION BY JOYCE HESSLEBERTH



bers to go back up in the coming years, Coyne adds, "What we've put more emphasis on is making sure we're commercializing our technologies more effectively."

Such is the innovation vortex—a swirling eddy of forces that compels companies to constantly switch strategies. Depending on where they are in the cycle, they patent madly or narrow focus—allowing for an explosion of patents followed by a reining-in of invention. The only constant in this maelstrom is change, lots of it and at a rapid clip.

Lou Galambos, a historian of business at Johns Hopkins University, calls rapid change—in all phases of corporate affairs—the leitmotif of a fundamental transformation in American business, the third in just over a century. The first was the great merger movement of the late 19th and early 20th centuries, which saw 4,200 firms collapse into about 250. A second transformation occurred after World War II, with the rise of the multidivisional, decentralized corporation. The current shift—the most powerful yet—began in the 1970s but didn't hit full stride until the 1990s. Here, U.S. companies lock horns with previously war-weakened Japanese and German rivals and a host of other international competitors. "Firms deal with an international economy with intense competition and unending pressures to innovate," Galambos asserts.

To help our readers understand this ever-shifting picture of competitiveness, *Technology Review* is unveiling its Patent Scorecard, which tracks the U.S. patenting activity of 150 leading firms in eight key industrial sectors. Patents are only one piece of the puzzle *(see "In Search of Innovation,"* TR *November/December 1999)*. But they're a key piece, and our scorecard, based on data from CHI Research of Haddon Heights, N.J., goes beyond patent numbers to try and assess the value of those inventions—based largely on how often they're cited in other patents. Indeed, the product of patent numbers and this "current impact index" is a value called technological strength, the basis of our rankings.

Even this is a far-from-certain indicator of a company's position—since, for

example, a dramatic falloff in tech strength could indicate either a declining firm or a highly innovative one narrowing its focus. But CHI has included two additional variables *(see box below)*. "Science linkage" tracks the scientific papers cited in each patent to evaluate the closeness of a company's portfolio to cutting-edge research, while "technology cycle time" assesses how rapidly firms are turning technology—their own and others'—into inventions. By combining these measures, the scorecard provides a unique way to spot changes in a firm's intellectual property strategy and strength before they're otherwise apparent.

Prolific Patenters

AND A LOT IS CHANGING. A COMPARISON of the 1999 leaders against the five-year averages shows that the firm occupying the top spot has changed in seven of eight industry groupings: Only IBM has rested undisturbed at the head of its class.

Even more telling than the shuffling of leaders are the dramatic gains or losses in technological strength that a host of companies have experienced in recent years. Take AT&T. The company ranked fourth in the telecommunications sector in 1999—behind Lucent, Motorola and Ericsson—just where its five-year average puts it. But last year's projected technological strength rating of 1551 is more than five times its average for the previous half-decade—enabling it to close the gap on the leaders. The movement reflects to a great extent the forces put in place following AT&T's 1995-96 trivestiture, which saw it split into AT&T, Lucent Technologies and NCR. "At the time of trivestiture...a much greater percentage of the patents that were held between the combined companies stayed with Lucent," says intellectual property executive George. That made sense, he says, because Lucent is a hardware and manufacturing concern, while AT&T operates as a long-distance and services company—and few patents had traditionally been granted in the service sector.

The rules have been rewritten in recent years, though, with the awarding of patents for seemingly not-so-inventive service ideas such as "experts online" *(see "Software Patents Tangle the Web," p. 68)*. In early 1998, the new service-friendly patenting environment helped spur chairman Armstrong to launch his campaign to bolster AT&T's patent output—not just for its traditional long-distance business, but in cable systems, wireless communications and Internet telephony.

Among those tapped to bring about this new era was AT&T fellow Roy Weber, who back in the old AT&T days had won the basic systems patent covering the use of 800 numbers to handle customer-service calls. Weber, now a research vice president, oversees a variety of service-related investigations. Among other things, AT&T is pushing his scheme for a customer service operation called Wide-area Internet Sales Link (WISL—pronounced "whistle"). The idea is to improve on the current geographically based call centers spurred by his 800 patent by creating virtual centers in which service agents share data over the Internet and phone calls are automatically routed to agents who are free.

The advantage, says Weber, is flexibility. Many companies needing to expand their service centers are struggling to find skilled people and construct buildings fast enough. "What WISL does is give them a degree of freedom. They can build centers anywhere—strip malls, satellite offices—or let people work from their homes," he says. AT&T has field tested WISL with a telemarketing service bureau in Florida and a Detroit-area travel service. Commercial rollout is planned for this year.

Another sign of the dynamic nature of invention these days is the way relative small fries can crack the big-boy ranks. In the biotech/pharmaceuticals arena, tiny Incyte Pharmaceuticals, a Palo Alto concern with about $150 million in sales, soared from 17th place in the five-year tech strength averages to tenth in 1999—surpass-

IP WATCH
Scorecard fold-out →

Enumerating Innovation

To navigate the global knowledge economy, it is essential to be able to understand the intellectual property strategies of your corporate competitors. To help you do that, *Technology Review* has teamed with CHI Research to produce the Patent Scorecard, an industry-by-industry ranking of the power of corporate patent portfolios.

Armed with 30 years of experience in developing the tools and techniques for measuring science and technology, CHI combines patent numbers with a variety of related indicators to help flesh out this deeper picture of innovation. Lacking complete 1999 year-end reports from the U.S. Patent Office, CHI extrapolated scorecard values from the first 47 weeks' worth of data.

Here are the specifics:

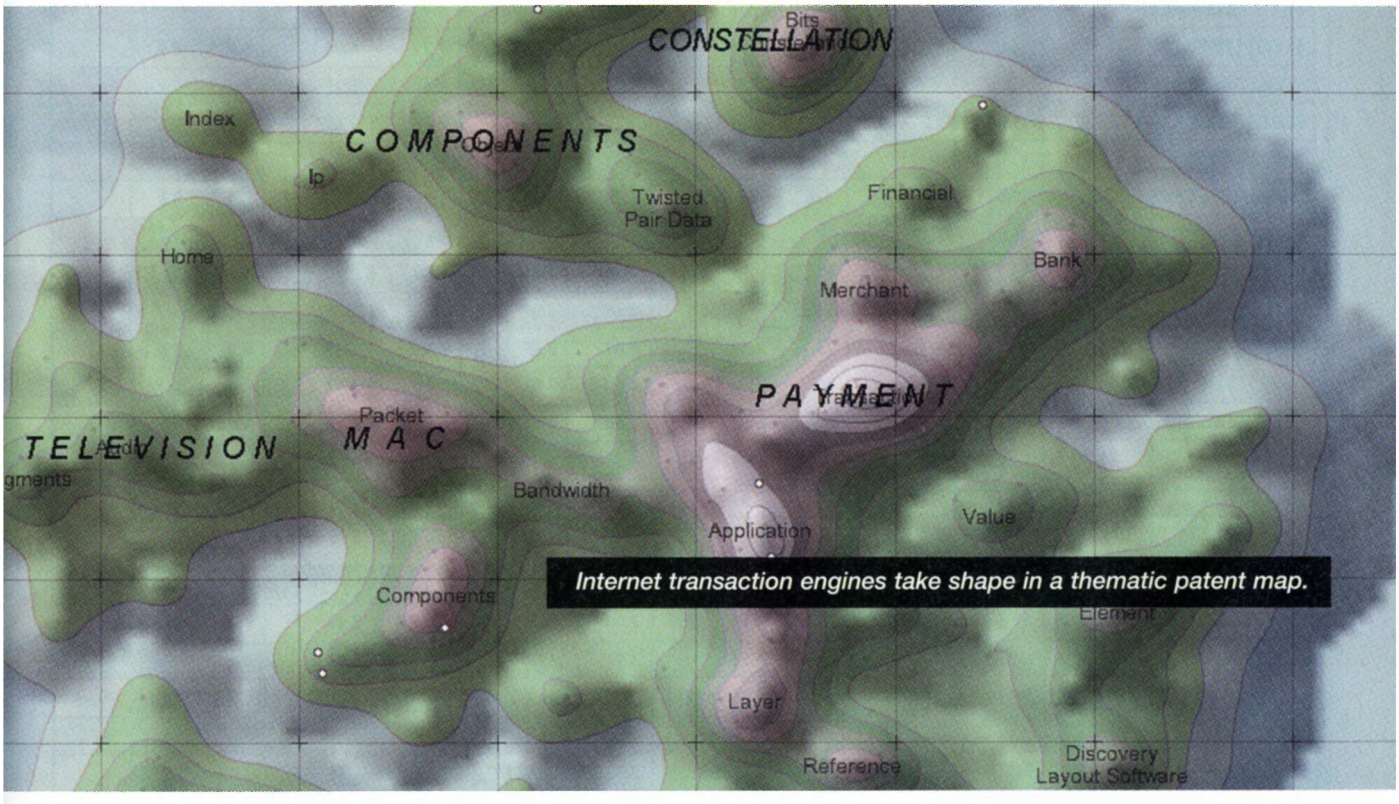
■ **Technology Strength:** This figure, the overall basis of the rankings, allows you to assess a firm's IP power at a glance. Calculated by multiplying the number of each company's U.S. patents by its Current Impact Index *(see below)*, this measure makes it easier to see how a company with a few key inventions might have the edge on competitors with greater numbers of less important patents.

■ **Current Impact Index:** To help examiners assess the novelty of an invention, patent applications must list the "prior art," typically in the form of references to previous patents. For this indicator, CHI shifts the equation and looks at how often a company's patents are cited as prior art in *subsequent* patents. Specifically, the index examines how often a company's previous five years of U.S. patents are cited in all the current year's batch. A value of 1.0 represents average citation frequency, 1.4 indicates a company's patents were cited 40 percent more often than average, and so on. This is a measure of the broader significance of a company's patents.

■ **Science Linkage:** Especially when an invention blazes a new trail in an area where there hasn't been much previous patenting, patents cite scientific papers as prior art. This value shows the average number of science references listed on a company's U.S. patents. A high figure indicates that a company is closer to the leading edge of research than its competitors.

■ **Technology Cycle Time:** An indicator of a firm's innovative speed, defined as the median age (in years) of the U.S. patent references cited on the company's patents. Companies with short cycle times are assumed to be rapidly turning cutting-edge technology into intellectual property.

PLOT



Internet transaction engines take shape in a thematic patent map.

The time has clearly arrived to either use your patent portfolio strategically, or lose. Fortunately, Aurigin's Intellectual Asset Management (IAM) solutions are available to give you an entirely new perspective.

Map your competition's patents on the intellectual asset landscape, and plot your course around them. Avoid blind alleys by identifying probable losers early in the development process. Organize your company's patent portfolio for revenue mining and uncover niche opportunities in a matter of hours or days, rather than months or years. Target merger and acquisition opportunities with precision and reduced risk.

Powerful new insights appear when you can actually print out the Big Picture, in full color, and put it up on the wall.

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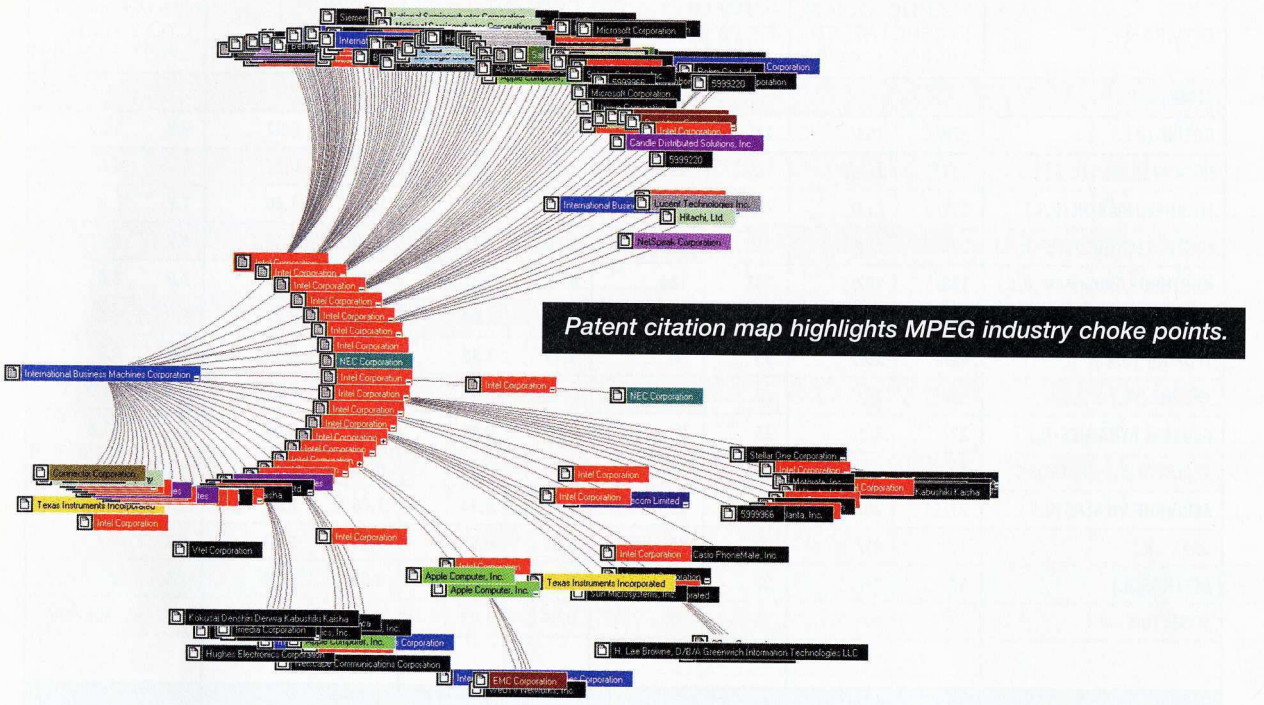

Patent citation map highlights MPEG industry choke points.

Aurigin's IAM solutions can accelerate pivotal decisions and reduce infringement risk. License-in new technology to bring new products to market faster. Penetrate markets with instant "build or buy" technology decisions. Achieve first-mover advantage by filing first. Learn what your competitors don't know about their own patent landscape.

IP WATCH

The Technology Review

Patent Scorecard

The numbers are in on 150 of the world's most inventive corporations.

COMPANY	TECHNOLOGICAL STRENGTH/RANK 1999*	1994-98†	NUMBER OF PATENTS 1999*	1994-98†	CURRENT IMPACT INDEX 1999*	1994-98†	SCIENCE LINKAGE 1999*	1994-98†	TECHNOLOGY CYCLE TIME 1999*	1994-98†
AEROSPACE										
BOEING (U.S.)	278/1	153/4	325	180	0.85	0.85	0.55	0.82	9.9	13.2
ROCKWELL INT'L (U.S.)	231/2	154/3	185	155	1.25	0.99	1.01	0.37	6.8	8.0
LOCKHEED MARTIN (U.S.)	218/3	212/2	229	243	0.95	0.87	1.49	1.40	7.8	8.6
UNITED TECHNOLOGIES (U.S.)	206/4	249/1	310	350	0.66	0.71	0.60	0.37	8.7	9.6
NORTHROP GRUMMAN (U.S.)	138/5	102/5	163	124	0.85	0.82	0.50	0.63	7.8	8.8
TEXTRON (U.S.)	48/6	77/6	53	77	0.91	1.00	0.10	0.27	8.0	9.9
TI GROUP (U.K.)	42/7	50/7	35	36	1.19	1.38	0.38	0.11	7.3	9.7
SNECMA (FR.)	31/8	36/8	63	73	0.49	0.50	0.35	0.19	8.5	11.9
GENERAL DYNAMICS (U.S.)	27/9	8/14	25	9	1.05	0.96	2.78	8.63	8.3	11.8
AEROSPATIALE GROUP (FR.)	23/10	33/9	48	68	0.48	0.48	0.30	0.30	9.2	10.5
AEROQUIP-VICKERS (U.S.)	22/11	20/11	20	23	1.09	0.84	1.06	0.83	8.1	8.5
GKN (U.K.)	17/12	21/10	28	37	0.62	0.57	0.00	0.02	8.1	9.7
DFVLR (GER.)	16/13	14/13	22	22	0.72	0.61	0.80	1.38	7.5	7.7
SEQUA (U.S.)	13/14	18/12	15	17	0.84	1.03	0.43	0.28	11.1	14.0
AUTOMOTIVE										
TOYOTA (JAP.)	700/1	331/5	487	259	1.44	1.28	0.30	0.35	5.8	6.1
HONDA (JAP.)	580/2	375/4	470	323	1.23	1.16	0.10	0.19	5.9	6.4
DENSO (JAP.)	527/3	403/3	438	320	1.20	1.26	0.28	0.29	6.8	6.6
GENERAL MOTORS (U.S.)	513/4	460/1	427	447	1.20	1.03	0.59	0.48	6.7	7.6
DAIMLER CHRYSLER (GER.)	493/5	328/6	511	405	0.96	0.81	0.31	0.22	7.7	8.4
TRW (U.S.)	465/6	323/8	330	204	1.41	1.58	0.77	0.59	6.9	7.5
FORD (U.S.)	446/7	439/2	404	378	1.10	1.16	0.33	0.31	7.4	8.2
BOSCH (GER.)	413/8	324/7	450	337	0.92	0.96	0.17	0.22	7.2	6.8
AISIN SEIKI (JAP.)	338/9	131/12	227	130	1.49	1.01	0.38	0.51	5.8	6.8
NISSAN (JAP.)	314/10	198/10	269	185	1.17	1.07	0.10	0.15	6.0	6.2
EATON (U.S.)	306/11	171/11	239	178	1.28	0.96	0.16	0.26	7.5	8.9
YAZAKI (JAP)	300/12	219/9	298	187	1.01	1.17	0.01	0.02	6.6	6.6
LEAR (U.S.)	298/13	62/17	162	56	1.85	1.11	1.49	0.37	8.4	8.9
YAMAHA (JAP.)	233/14	95/14	177	139	1.32	0.68	0.00	0.02	6.7	8.9
CUMMINS ENGINE (U.S.)	153/15	70/15	116	62	1.32	1.12	0.20	0.21	8.3	10.7
DELPHI AUTOMOTIVE (U.S.)	131/16	102/13	106	92	1.23	1.11	0.25	0.25	5.6	6.9
BREED TECHNOLOGIES (U.S.)	115/17	26/18	60	13	1.92	1.94	0.02	0.06	4.9	6.7
MITSUBISHI (JAP.)	101/18	68/16	61	50	1.65	1.35	0.00	0.06	5.1	5.6

* estimated from 47-week data; † average

COMPANY	TECHNOLOGICAL STRENGTH/RANK 1999*	1994-98†	NUMBER OF PATENTS 1999*	1994-98†	CURRENT IMPACT INDEX 1999*	1994-98†	SCIENCE LINKAGE 1999*	1994-98†	TECHNOLOGY CYCLE TIME 1999*	1994-98†
BIOTECH/ PHARMACEUTICALS										
MERCK (U.S.)	246/1	180/4	254	205	0.97	0.88	5.85	6.42	5.7	6.4
SMITHKLINE BEECHAM (U.K.)	227/2	43/18	251	80	0.91	0.54	5.43	3.18	7.1	8.1
PFIZER (U.S.)	195/3	174/5	153	141	1.28	1.24	2.77	2.59	7.1	7.8
ROCHE (SWITZ.)	180/4	215/1	248	275	0.73	0.78	15.46	14.61	8.2	8.5
ELI LILLY (U.S.)	171/5	141/8	183	183	0.94	0.77	7.65	9.46	6.6	9.0
BRISTOL-MYERS SQUIBB (U.S.)	155/6	156/7	169	172	0.92	0.91	10.12	7.44	8.9	8.3
AMERICAN HOME PRODUCTS (U.S.)	149/7	204/3	226	222	0.66	0.92	7.38	6.66	7.3	7.9
NOVO NORDISK (DEN.)	133/8	69/10	218	98	0.61	0.71	5.52	7.22	6.8	8.1
NOVARTIS (SWITZ.)	133/9	205/2	208	341	0.64	0.60	11.26	4.59	8.9	9.6
INCYTE PHARM. (U.S.)	127/10	44/17	248	27	0.51	1.62	8.79	12.70	4.3	5.5
ABBOTT LABORATORIES (U.S.)	124/11	168/6	149	163	0.83	1.03	7.79	4.08	9.6	8.9
ASTRAZENECA (U.K.)	121/12	109/9	211	143	0.57	0.76	6.60	5.17	8.2	8.0
GLAXO WELLCOME (U.K.)	115/13	52/15	90	74	1.29	0.70	8.26	9.85	7.7	8.6
SCHERING-PLOUGH (U.S.)	113/14	36/21	110	63	1.03	0.58	12.06	8.82	7.6	10.2
PHARMACIA & UPJOHN (U.S.)	109/15	64/12	139	104	0.78	0.61	14.71	9.16	8.1	9.0
ISIS PHARMACEUTICALS (U.S.)	103/16	38/20	67	24	1.53	1.56	36.61	38.87	6.9	6.4
ALZA (U.S.)	92/17	35/22	56	34	1.63	1.04	2.90	2.40	10.4	10.3
GENERAL HOSPITAL (U.S.)	84/18	45/16	86	42	0.97	1.07	36.62	32.79	7.9	8.1
SCHERING (GER.)	61/19	41/19	73	59	0.84	0.69	4.95	4.19	8.9	8.6
TAKEDA CHEMICAL (JAP.)	61/20	60/13	94	95	0.65	0.63	5.29	2.57	8.3	8.9
WARNER-LAMBERT (U.S.)	55/21	67/11	80	83	0.69	0.81	8.69	6.19	9.8	9.4
XOMA (U.S.)	51/22	19/23	15	12	3.27	1.55	41.29	44.35	4.7	5.9
CHIRON (U.S.)	49/23	53/14	74	53	0.67	1.00	42.57	29.25	8.9	9.0
CHEMICALS										
PROCTER & GAMBLE (U.S.)	1115/1	664/2	557	341	2.00	1.95	1.05	2.09	9.4	10.2
3M (U.S.)	621/2	749/1	472	546	1.31	1.37	3.04	2.00	9.2	10.3
DUPONT (U.S.)	380/3	396/3	520	483	0.73	0.82	4.72	3.16	8.9	9.9
BASF (GER.)	302/4	243/7	514	459	0.59	0.53	1.70	0.95	8.8	10.5
BAYER (GER.)	260/5	254/6	522	508	0.50	0.50	2.49	1.74	8.4	9.3
SHIN-ETSU CHEMICAL (JAP.)	205/6	129/12	233	190	0.88	0.68	0.43	0.39	6.4	7.7
CABOT (U.S.)	205/7	13/17	44	12	4.63	1.07	5.00	5.54	8.2	9.9
MONSANTO (U.S.)	201/8	137/10	248	193	0.81	0.71	12.96	8.30	9.9	9.4
DOW CHEMICAL (U.S.)	189/9	204/8	180	265	1.05	0.77	5.23	3.80	9.1	9.9
DOW CORNING (U.S.)	169/10	138/9	206	166	0.82	0.83	0.81	0.77	8.7	9.1
RHONE POULENC (FR.)	164/11	115/13	236	209	0.70	0.55	8.37	3.59	9.0	10.4
HOECHST (GER.)	162/12	300/4	330	556	0.49	0.54	5.26	3.08	9.0	9.4
ROHM AND HAAS (U.S.)	160/13	260/5	160	211	1.00	1.23	1.01	0.71	7.7	7.9
HENKEL (GER.)	135/14	114/14	189	173	0.72	0.66	1.53	1.23	9.2	12.4
BRIDGESTONE (JAP.)	135/15	93/15	167	122	0.81	0.76	0.88	1.23	8.4	10.8
AGFA (GER.)	120/16	131/11	195	168	0.62	0.78	0.07	0.15	6.7	7.3
DEGUSSA-HÜLS (GER.)	118/17	92/16	189	161	0.62	0.57	0.87	0.74	7.1	8.9
COMPUTERS										
IBM (U.S.)	6895/1	3888/1	2736	1800	2.52	2.16	1.01	1.31	5.6	6.1
NEC (JAP.)	2857/2	1608/2	1912	1218	1.49	1.32	0.65	0.70	4.8	5.1

* estimated from 47-week data; † average

COMPANY	TECHNOLOGICAL STRENGTH/RANK 1999*	1994-98†	NUMBER OF PATENTS 1999*	1994-98†	CURRENT IMPACT INDEX 1999*	1994-98†	SCIENCE LINKAGE 1999*	1994-98†	TECHNOLOGY CYCLE TIME 1999*	1994-98†
FUJITSU (JAP.)	2153/3	1261/3	1269	920	1.70	1.37	0.64	0.66	5.5	5.8
SUN MICROSYSTEMS (U.S.)	2083/4	433/10	559	168	3.73	2.58	1.91	1.70	4.2	4.5
HEWLETT-PACKARD (U.S.)	1558/5	977/5	850	565	1.83	1.73	1.15	1.40	6.0	6.5
MICROSOFT (U.S.)	1441/6	463/7	361	142	3.99	3.26	2.61	1.77	4.4	4.6
COMPAQ (U.S.)	1403/7	924/6	415	342	3.38	2.70	0.77	1.24	4.6	6.3
XEROX (U.S.)	1051/8	1029/4	644	655	1.63	1.57	0.93	0.87	6.5	6.4
RICOH (JAP.)	584/9	453/8	422	343	1.39	1.32	0.28	0.35	6.1	5.6
SEIKO EPSON (JAP.)	526/10	319/11	310	210	1.70	1.52	0.68	0.83	7.4	7.0
APPLE COMPUTER (U.S.)	496/11	450/9	178	161	2.78	2.80	1.29	1.36	5.2	5.2
NCR (U.S.)	429/12	172/14	193	112	2.23	1.54	0.78	0.61	5.9	6.7
SEAGATE (U.S.)	355/13	186/13	177	99	2.01	1.88	0.64	0.55	6.1	6.5
NOVELL (U.S.)	347/14	42/18	58	11	6.03	3.99	3.63	2.62	4.6	4.0
OKI (JAP.)	338/15	133/15	242	103	1.39	1.29	0.61	0.58	5.0	5.2
ORACLE (U.S.)	331/16	60/16	89	21	3.74	2.81	1.49	1.10	3.5	4.7
CISCO SYSTEMS (U.S.)	324/17	57/17	55	13	5.85	4.30	0.92	0.92	5.4	4.6
FUJI XEROX (JAP.)	290/18	233/12	249	197	1.16	1.13	0.62	0.74	5.3	5.5
ELECTRICAL/ELECTRONICS										
SAMSUNG (KOR.)	2347/1	956/6	1705	790	1.38	1.21	0.15	0.19	5.3	5.6
CANON (JAP.)	2102/2	1897/1	1774	1437	1.19	1.32	0.49	0.52	7.6	7.2
SONY (JAP.)	1970/3	1280/3	1421	941	1.39	1.36	0.31	0.36	5.6	5.7
TOSHIBA (JAP.)	1926/4	1347/2	1294	1060	1.49	1.27	0.62	0.63	5.7	6.0
HITACHI (JAP.)	1869/5	354/13	1280	264	1.46	1.34	0.76	0.82	6.3	6.7
MATSUSHITA (JAP.)	1588/6	1209/4	1233	1007	1.29	1.20	0.52	0.68	6.0	5.9
MITSUBISHI ELECTRIC (JAP.)	1527/7	1161/5	1109	1018	1.38	1.14	0.61	0.77	5.8	5.9
PHILIPS (NETH.)	1269/8	755/9	999	719	1.27	1.05	0.51	0.67	5.9	6.4
EASTMAN KODAK (U.S.)	1007/9	940/7	987	862	1.02	1.09	0.31	0.44	7.3	8.1
SIEMENS (GER.)	930/10	596/11	995	693	0.93	0.86	0.66	0.83	6.9	7.2
SHARP (JAP.)	783/11	544/12	568	461	1.38	1.18	0.78	0.78	5.1	5.6
LG ELECTRONICS (KOR.)	676/12	328/15	575	345	1.18	0.95	0.24	0.22	5.1	5.7
TYCO INT'L (U.S.)	560/13	651/10	419	449	1.34	1.45	0.89	0.60	8.8	9.6
GENERAL ELECTRIC (U.S.)	559/14	799/8	708	815	0.79	0.98	0.55	0.64	8.3	9.3
MINOLTA (JAP.)	408/15	195/18	344	181	1.18	1.08	0.05	0.03	6.8	6.4
TOKYO ELECTRON (JAP.)	354/16	180/20	143	94	2.48	1.91	0.22	0.07	6.3	5.2
DAEWOO (KOR.)	349/17	205/17	281	146	1.24	1.40	0.06	0.18	5.4	6.3
BROTHER INDUSTRIES (JAP.)	335/18	146/22	268	161	1.25	0.91	0.03	0.04	5.7	6.1
MURATA MFG (JAP.)	325/19	139/23	252	148	1.29	0.94	0.26	0.21	6.5	7.7
RAYTHEON (U.S.)	281/20	344/14	254	334	1.11	1.03	0.48	0.91	7.9	7.7
SANYO (JAP.)	281/21	173/21	245	164	1.15	1.06	0.63	0.54	5.8	6.0
TRIMBLE NAVIGATION (U.S.)	274/22	110/24	76	37	3.59	2.98	0.30	0.30	5.8	5.2
YAMAHA (JAP.)	268/23	181/19	205	149	1.31	1.21	0.24	0.22	5.0	5.5
THOMSON (FR.)	268/24	246/16	278	280	0.96	0.88	0.67	0.62	7.2	7.3
SEMICONDUCTORS										
MICRON TECHNOLOGY (U.S.)	3470/1	757/3	1047	319	3.32	2.37	1.80	0.90	5.3	5.3
ADVANCED MICRO DEVICES (U.S.)	2376/2	569/4	814	247	2.92	2.30	1.01	1.15	5.0	5.3
INTEL (U.S.)	2236/3	1163/1	758	410	2.95	2.84	0.97	0.84	5.2	4.9
TEXAS INSTRUMENTS (U.S.)	1013/4	952/2	590	580	1.72	1.64	1.14	1.28	5.9	6.4

* estimated from 47-week data; † average

COMPANY	TECHNOLOGICAL STRENGTH/RANK 1999*	1994-98†	NUMBER OF PATENTS 1999*	1994-98†	CURRENT IMPACT INDEX 1999*	1994-98†	SCIENCE LINKAGE 1999*	1994-98†	TECHNOLOGY CYCLE TIME 1999*	1994-98†
LSI LOGIC (U.S.)	961/5	321/7	334	137	2.88	2.34	2.19	1.59	6.0	5.9
SEMICONDUCTOR ENERGY LAB. (JAP.)	844/6	112/12	180	85	4.68	1.31	2.37	1.39	5.6	6.5
TAIWAN SEMICONDUCTOR MFG (TAIWAN)	731/7	196/9	275	91	2.65	2.15	0.12	0.22	4.5	4.0
STMICROELECTRONICS (FR.)	624/8	382/5	417	296	1.50	1.29	0.93	0.98	6.5	6.3
UNITED MICROELECTRONICS (TAIWAN)	516/9	246/8	249	138	2.07	1.78	0.25	0.33	4.4	4.2
NATIONAL SEMICONDUCTOR (U.S.)	371/10	338/6	190	196	1.95	1.72	1.13	1.59	5.6	5.8
VANGUARD INT'L SEMICONDUCTOR (TAIWAN)	354/11	101/13	105	39	3.37	2.57	0.24	0.26	4.3	3.6
XILINX (U.S.)	284/12	160/10	92	48	3.09	3.34	0.67	1.28	5.3	5.0
CYPRESS SEMICONDUCTOR (U.S.)	257/13	87/14	113	41	2.27	2.12	1.19	0.95	5.5	4.8
WINBOND ELECTRONICS (TAIWAN)	235/14	16/17	110	19	2.14	0.85	0.17	0.40	4.0	4.6
ALTERA (U.S.)	198/15	116/11	69	30	2.89	3.88	2.02	2.19	6.9	5.9
LAM RESEARCH (U.S.)	154/16	41/15	54	19	2.84	2.13	1.14	0.59	6.1	6.4
TESSERA (U.S.)	142/17	27/16	29	11	4.92	2.47	0.69	0.51	8.2	8.0
TELECOMMUNICATIONS										
LUCENT TECHNOLOGIES (U.S.)	2592/1	1473/2	1137	759	2.28	1.94	1.24	1.96	5.4	5.3
MOTOROLA (U.S.)	2320/2	1978/1	1207	1093	1.92	1.81	0.55	0.77	5.2	5.5
ERICSSON TELEPHONE (SWE.)	1758/3	448/3	635	209	2.77	2.14	0.89	1.69	5.4	6.0
AT&T (U.S.)	1551/4	291/4	318	69	4.88	4.22	1.18	1.10	4.4	4.9
BCE (CAN.)	754/5	230/7	281	125	2.68	1.84	0.94	1.14	4.8	4.9
NOKIA (FIN.)	629/6	175/10	287	123	2.19	1.42	0.56	0.51	5.0	5.6
QUALCOMM (U.S.)	541/7	282/5	106	42	5.09	6.77	0.98	1.65	7.0	6.2
MCI WORLDCOM (U.S.)	445/8	139/12	128	38	3.46	3.71	1.45	0.80	4.6	4.5
ALCATEL (FR.)	331/9	274/6	254	256	1.30	1.07	0.94	1.13	6.6	6.5
CABLETRON SYSTEMS (U.S.)	271/10	67/14	35	9	7.67	7.33	1.41	3.35	4.5	4.8
BELL ATLANTIC (U.S.)	219/11	165/11	34	37	6.40	4.42	0.68	1.85	6.2	5.9
NIPPON TELEGRAPH AND TELEPHONE (JAP.)	216/12	195/8	117	113	1.84	1.73	1.57	2.09	4.8	5.2
US WEST (U.S.)	162/13	51/16	40	16	4.07	3.13	1.19	1.17	5.4	4.6
BRITISH TELECOMMUNICATIONS (U.K.)	119/14	67/14	77	53	1.54	1.27	2.67	3.56	5.5	6.3
ADC TELECOM (U.S.)	109/15	18/19	32	14	3.39	1.36	0.14	1.57	5.9	8.4
BELLSOUTH (U.S.)	108/16	28/18	24	13	4.44	2.12	0.36	0.52	5.7	6.2
SCIENCE APPLICATIONS INTERNATIONAL (U.S.)	105/17	177/9	24	60	4.33	2.96	3.68	2.78	5.3	5.2
SCIENTIFIC-ATLANTA (U.S.)	92/18	73/13	29	30	3.19	2.40	0.46	2.04	5.9	7.4
KOKUSAI DENSHIN DENWA (JAP.)	84/19	37/17	45	22	1.85	1.69	0.71	0.92	4.5	4.6

The Nitty-Gritty

Technological Strength: The number of U.S. patents multiplied by the Current Impact Index (see below).

Number of Patents: The total number of U.S. patents awarded, excluding design and other special-case inventions.

Current Impact Index: Number of times a company's patents for the previous five years are cited in the current year, relative to all patents in the U.S. system. A value of 1.0 indicates average citation frequency.

Science Linkage: The average number of science references cited in a company's U.S. patents.

Technology Cycle Time: Median age in years of the U.S. patent references listed on a company's patents.

* estimated from 47-week data; † average

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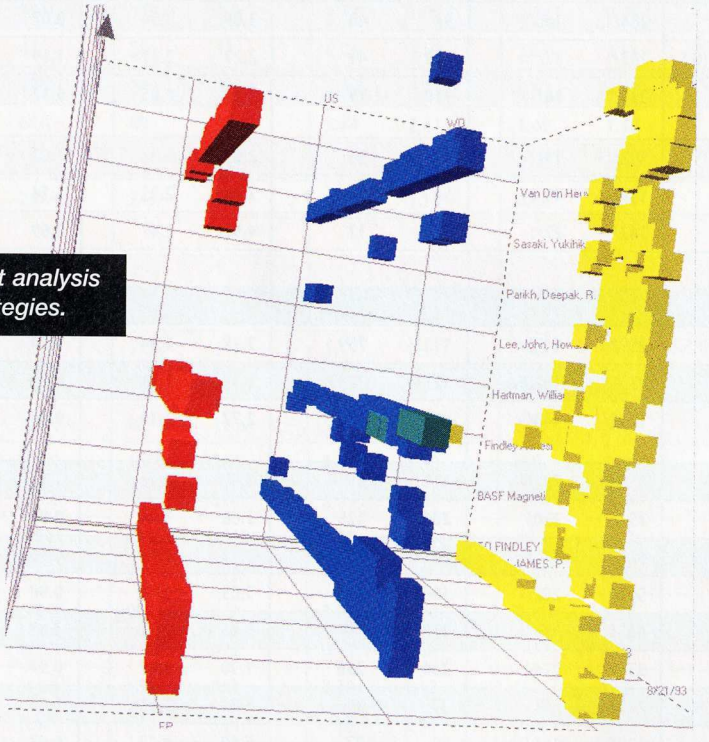

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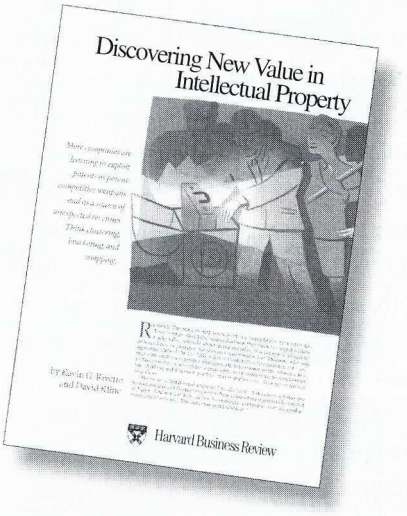

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AURIGIN

THE Bell Labs OF Biology

It's a hot new institute, combining the research capabilities of a university and a big pharmaceutical company. Its director, Peter Schultz, who has already helped to revolutionize drug discovery, is setting his sights on understanding cancer, aging and memory.

PHOTOGRAPHS BY BROMBERGER & HOOVER

Q & A

IT'S THE ULTIMATE JIGSAW PUZZLE. By next year, biologists are scheduled to finish sequencing the entire set of human genes. The Human Genome Project has been a mammoth endeavor involving thousands of scientists and billions of dollars. But for Peter Schultz, the real fun—understanding how all those genes function—is just beginning.

Last year, Schultz quit as chemistry professor at the University of California, Berkeley, to start up the Genomics Institute of the Novartis Research Foundation at La Jolla, Calif. The purpose of the $250 million institute, funded by the Novartis Research Foundation (a Swiss foundation with close ties to pharmaceutical giant Novartis) is to elucidate the biological meaning of the hundreds of thousands of genes detailed by the genome project. The work of assembling that puzzle is known as functional genomics, and Schultz leaves no doubt that he expects his institute to lead this race to understand, molecule by molecule, how the human body works.

Coming from most people, that would sound like idle boasting. But Schultz has the track record to back it up. Part entrepreneur, part research administrator, part organic chemist, Schultz has always been intent on turning lab advances into real-world technologies. Starting in the late 1980s, he was one of the pioneers of "combinatorial chemistry," a collection of techniques for rapidly generating huge numbers of compounds and screening them for specific kinds of activity. Many researchers would have been content to stop there.

Not Schultz, who played a pivotal role in turning this seemingly esoteric advance into a revolution in the search for new drugs and materials. Affymax, a combinatorial chemistry startup Schultz helped found in 1989, has changed the way pharmaceutical companies hunt for new compounds, while Symyx, which he cofounded in 1995, has used similar combinatorial technology to revolutionize the discovery of electronic materials and catalysts *("Winning Combination,"* TR *May/June 1998).* In his latest incarnation, Schultz plans to use some of these same chemistry tricks to understand everything from human cognition to human development.

In his office by 5:00 a.m., Schultz maintains a hectic schedule. In addition to heading up the new genomics institute—which began operations last summer—Schultz serves as a director of several startup companies and maintains his presence in academia by running a 40-member lab at the Scripps Research Institute. Senior Editor David Rotman caught up with Schultz early one morning to hear about his plans for the institute and the increasing role of chemistry in biomedical research—and to get an update on the effort to put together the vast jigsaw puzzle of human genes.

TR: What is functional genomics? Why has it become such a hot topic in biology and biotechnology?

SCHULTZ: There are between 100,000 and 200,000 distinct genes in the human genome. The sequence [of the entire human genome] will probably be complete this year or next and be in the public domain in 2002. The most immediate impact the gene sequence will have on the average person is in the development of new diagnostics for disease and new targets for drug development. The question is, what are the cellular and physiological functions of those genes? And how can we modulate those functions to, for example, treat disease?

TR: Answering those questions is the mission of your institute?

SCHULTZ: Yes, we want to deduce the function of a particular gene product [each gene codes for a protein], then learn how that protein interacts with other molecules in an organism and how to modulate the function of that particular protein. We want to understand the function of these proteins and their role in the cell and organism. The result will hopefully be the ability to create small molecules, proteins or genes themselves that act as human therapeutics.

TR: You left the University of California, Berkeley, and Howard Hughes Medical Institute to head the new institute. What was the attraction?

SCHULTZ: The sequence of the human genome is determined once in the history of mankind. It's a unique time in biology and chemistry—equivalent to the advent of quantum mechanics in physics. The question is—how do we begin to understand and assimilate the huge amount of information encoded in the genome? The other revolution that has occurred during the last 10 years in the biological and physical sciences is in the way in which we carry out experimental science. There's been a tremendous increase in our ability to design, implement and analyze experiments—to carry them out not one at a time but thousands or millions at a time. That has been made possible by combinatorial technologies, computational tools and advances in engineering and miniaturization—the kind of tools and processes that revolutionized the semiconductor industry are being moved over into the biological and physical sciences. The bottom line is that without that set of tools it would be damn near impossible to deal with the huge amount of information related to the human genome.

TR: Aren't there a lot of other research groups working in the field of functional genomics these days? In other words, isn't there a lot of competition out there for the institute?

SCHULTZ: But very few people have attempted to bring together all the tools under one roof and use them synergistically to understand gene function. That's what we're trying to do. It's something that's difficult in a conventional university setting, because it requires focused efforts and dedicated resources. It's difficult to do in biotech companies because they usually have one mission or goal. And it's difficult to do in a big pharmaceutical company because there's a product focus. I view this place as a new Bell Labs of biology: a tremendous technological infrastructure with small, highly collaborative groups.

One revolution is our ability to carry out experiments thousands or millions at a time. Without these types of tools it would be damn near impossible to deal with the huge amount of information related to the human genome.

TR: What do you anticipate will be the payoff? Will it lead to faster or more efficient drug discovery?

SCHULTZ: The mission isn't drug discovery. It's biological discovery and improved technologies for making those discoveries. But the point is that nowadays very little time passes between when an important biological advance is made and when people begin to try and exploit that advance for human therapeutics. If someone makes a discovery involving the underlying molecular basis for Alzheimer's disease, the next day the pharmaceutical industry will begin implementing drug discovery programs based on that new insight. Likewise, if you discover what genes are important in longevity, or in cognition, that's a fundamental scientific discovery, but very shortly thereafter those gene products become targets for the development of therapeutics. That fact allows a place like this to focus on biological discovery with the expectation that it's going to lead to important biomedical advances.

TR: Hence the Novartis Research Foundation's interest in funding the institute.

SCHULTZ: Exactly. I think that Paul Herrling [head of research at Novartis] realized there needed to be a place that brought together many of these tools and focused them on the opportunity created by the genome sequence. There weren't such places in either the academic world or industrial world. We're somewhere between university and biotech-pharmaceutical research. This is really an experiment. And the reason that the Novartis Research Foundation is willing to support us is their realization that there's a very thin line between basic research and new opportunities for the development of therapeutics.

TR: You've been involved in startup companies and academia, and now you're associated with a large pharmaceutical company. What are the tradeoffs of each in terms of the innovation process?

SCHULTZ: I retain my "academic" hat at the Scripps Research Institute. But the problem with academia is it's very hard to focus resources like one can do in industry. On the other hand, companies sooner or later tend to become very product-focused because they have shareholders wanting value. At this institute we have the opportunity to have our cake and eat it too. As we make discoveries or develop tools that have commercial value we can pass on those discoveries through the foundation to Novartis and they can use them to develop drugs; if Novartis isn't interested, we can spin off startups that can develop and apply the technology at a high level. The institute is free to continue developing new tools and making new discoveries. You just can't do that in academia. You can't focus resources like that because it's a democracy and everyone has a vote.

TR: What are some of the specific technologies that you're focusing your resources on?

SCHULTZ: We're developing a range of tools and applying them to the discovery of new biology at the molecular, cellular and organism level. For example, at the molecular level we're analyzing what genes get selectively expressed during fertilization, aging, learning or in neurodegenerative disease and cancer. At the same time, we're setting up high-throughput screens for molecules that affect function at the cellular level, for example, the differentiation of stem cells into various cell types and the entry of viruses into cells. We're also carrying out discovery at the level of the whole organism. For example, we're setting up a mouse screen in which we're going to randomly mutate a large number of genes in the mouse genome and carry out high-throughput phenotypic screens. One can screen for fat mice, thin mice, smart mice, dumb mice, mice that are pain-insensitive—or even long-lived mice. One can examine thousands of mutant mice for interesting phenotypes and then use the genomic tools that we and others are developing to map and clone the interesting gene mutations.

TR: You've done pioneering work in a number of areas. A few that come to mind are catalytic antibodies and combinatorial chemistry for finding new materials. Is there a common theme in your work?

SCHULTZ: I'm a chemist and am interested in molecules and molecular functions—what molecules do and how that is related to their structures. Chemistry is moving from a focus on the structures of molecules to a focus on the functions of molecules. And if you're interested in molecular function, you should understand that nature has already solved the problem of making a remarkable array of functional molecules. For example, nature solved the problem of molecular recognition with the immune system and antibodies (a major line of defense against pathogens). Instead of making one antibody, and testing one antibody at a time for its ability to bind to a foreign molecule, it makes billions at a time and tests them all. That's a combinatorial approach. We've taken that idea and used it to search for interesting new catalysts. We've even taken that strategy and applied it to making libraries of materials and searching for novel optical, magnetic and electronic materials. I think there's basically a limitless opportunity in the periodic table. The underlying theme is how you do experiments thousands at a time and analyze the data thousands at a time.

TR: I found it interesting that a genomics research center chose as its director a chemist.

SCHULTZ: It is strange. On the other hand, it's strange that an organic chemist/biological chemist started a materials science company [Symyx] too. But I think that it's less strange now that I'm here. Because what genomics, the gene sequence, and all these tools are making possible is an understanding of biology at a molecular level. And as soon as you're talking about something at a molecular level, it's chemistry. A chemist is also not a bad choice in the sense that all these tools bridge biology, chemistry, physics, engineering and computation—and a chemist is a scientific jack-of-all-trades. However, it does mean that I've

If you begin to understand how different cells work together in asthma, inflammation or organ rejection, you can become a lot more sophisticated in the development of therapeutics for the immune system.

spent a lot of my time learning a lot of cell biology over the last year—let's put it that way.

TR: You've been involved in a couple of very successful startup companies. Any future plans?

SCHULTZ: I was a founding scientist at Affymax, then I was a founder of Symyx. Now we're forming a third company, which we're spinning out of the institute. Some of the structural genomics tools we're developing here will be the basis for the startup.

TR: What's its name?

SCHULTZ: I think it's going to be called Syrrx. I have good luck with companies that end with an X.

TR: Structural genomics, as opposed to functional genomics?

SCHULTZ: Right. Structural genomics involves the determination of the three-dimensional structures of proteins on a genome-wide scale. The idea we're pursuing at the institute is to carry out high-throughput protein structure determination and then virtual docking of small molecules to identify compounds that bind and modulate the activity of these proteins. If you can input 200,000 or 400,000 compounds in a computer, and actually dock *in silico* this entire library of molecules against a particular protein structure, one could, in theory, virtually identify leads for new drugs. We're developing these new technologies at the institute, but we don't have the resources to commit 100 people just to structural genomics. With the startup, we can put together the resources necessary to really exploit the technology.

TR: Ten years from now, what kind of research will we be talking about?

SCHULTZ: In 10 years, we won't be talking about the functions of individual proteins or individual cells but about the functions of networks—how collections of proteins in the cell, and collections of cells in the immune system or in the brain, function together. It's like in information science—it's not the individual bit, it's the integrated circuit. In biology it's going to be pathways and networks.

TR: And what will that increased understanding of pathways and networks mean in terms of developing therapeutics?

SCHULTZ: For instance, if you want therapeutics for cognition, it may not be good enough to understand the function of an individual protein or even an individual cell; you have to understand how those cells work together. Memory is not associated with one neuron. It's associated with a network. Once we begin to understand pathways and networks, in theory we can make therapeutics that modulate activities that rationally affect the properties of the entire network. We should become a lot more effective in the development in therapeutic agents.

TR: And gain the ability to take on different types of functions?

SCHULTZ: Exactly. The immune system is another example. If you begin to understand how all the different cells work together in asthma, inflammation or organ rejection, you can become a lot more sophisticated in the development of therapeutics. The same thing is true in cancer. Most of the drugs we use to kill cancer today do so by basically targeting rapidly dividing cells. That's not a very sophisticated approach. As you begin to better understand how cancer cells are different from a normal cell, you should be able to develop more selective drugs.

TR: I take it from what you say that there's still a long way to go in understanding these bio-networks.

SCHULTZ: It's a difficult problem because you have to figure out the function of individual proteins before you can figure out how they work together. If you look at a car and want to understand how it works, you look at the cylinders, the pistons, the valves, the spark plugs—and once you understand what each of those does, then you can begin to see how they all work together. It's the same thing here. You have to look at the functions of the individual proteins in a cell, and then you can start to understand how they work together.

TR: At this point, it's still pretty much looking at...

SCHULTZ: ...the spark plugs. And the problem is that we don't even have the whole list of the parts. We're still collecting the list of all the parts, while we're trying to figure what they do individually. The next level is to figure out how all the parts work together. That's the analogy to the cell. And then you go from the individual cell—there are billions of neurons in the brain—to understand how all those cells work together to make an organ.

The goal is to understand life at a molecular level. And if that's the goal, chemists will have to play a key role. ◊

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Strategic Patience

BACK IN 1985, WHILE RESEARCHING MY FIRST book, *Invisible Frontiers,* I had a lunchtime appointment with Robert Swanson, then president and CEO of Genentech. While en route to the interview, I found myself snarled in one of those now-familiar traffic jams on southbound U.S. 101—traffic jams created in part by the biotech revolution Swanson helped launch. I arrived an hour and a half late, in an advanced state of mortification, but Swanson betrayed not the slightest irritation. We repaired to the cafeteria, where he recalled the early days at Genentech with passion and humor.

The passionate and patient aspects of this man came to mind with the tragic news last December that Swanson, who founded Genentech in 1976 with biologist Herbert Boyer, had died of a brain tumor just a few days after his 52nd birthday. There have been generous and entirely fitting testimonials to Swanson's role as father of the biotechnology industry, but when I think back to the fitful start of our interview, I'm struck by a personality trait of Swanson's that might well serve as a philosophical statement about innovation. I'm sure he was more peeved than he let on, but patience was the better part of valor. That is what I remember most about Swanson: a strategic patience.

His supply of patience, let me hastily add, wasn't infinite. Having spoken with many of the scientists who formed the core of Genentech's original research staff, I know that Swanson could hector and pester and hover and noodge with the best of them. In a nascent field where practical applications were still largely theoretical, he understood the need to have a product sooner rather than later, and he shrewdly chose two targets—insulin and human growth hormone—in part because they already enjoyed a large infrastructure of knowledge both in academia and at the Food and Drug Administration. But he also understood that recombinant DNA technology, and every unimaginable thing that might eventually flower from it, would ultimately transform both science and pharmaceutical commerce. It was just a matter of time. Hence, patience.

Patience is a word—and concept—increasingly quaint in today's go-go high-tech agora. For several years now, we've read *ad nauseam* about the rags-to-riches sagas of twenty-something dot-com dervishes who have yet to produce a product, much less a profit, and often have nothing to sell but a frisky vision of the future. Compared to Web commerce, biotechnology products seem almost Victorian in the pace and fussiness of their creation: You not only have to deal with the humbling complexity and messiness of human biology, you have to, like, *get it approved, dude.* Why would a venture capitalist invest in an industry where the risk is so high, the endpoint so uncertain and the time horizon to product so distant, where the fate of an entire company can hinge on the whims of the FDA or the swoon of a single patient in a clinical trial, when staggeringly high returns are routinely available from the e-fad of the month?

That's a very good question if, to paraphrase Vince Lombardi, return on investment isn't the most important thing—it's the only thing. But at the risk of sounding like a socialist leftover, I keep coming back to a thought elicited by Bob Swanson's death. If the system confers no reward for patience, no economic payback for waiting out the development of life-transforming biomedical products that take time to mature, then the landslide vote of venture capital for software, Web accessories and digital ephemera in effect establishes that there is less value, cultural as well as financial, in the creation of new medicines.

Bob Swanson, the founder of Genentech, embodied virtues that today's venture capitalists are badly in need of.

And yet intuitively we know that's not true. The drugs that have emerged from the new biology required enormous patience (and, yes, capital), but they have been life-transforming in a manner altogether more rarified and precious than a better word-processing program or a faster chip. Protease inhibitors, monoclonal antibodies to fight breast cancer and leukemia, cytokines like interferon to treat cancer and multiple sclerosis, to name a few, have provided the ultimate in high-yield returns: lives reclaimed from imminent death. But the promised land in biomedicine is not for kids or amateurs precisely because of the amount of time it takes to get there. Not many have the patience, or courage, to tackle the road ahead when it winds through human biology.

I don't want to sound naive about the kind of patience Bob Swanson exemplified. Modest and private as he was, Swanson was definitely in it for the money, as he made clear one summer night long ago when he stood before the imposing Northern California estate of the legendary venture capitalist Thomas Perkins with two of his young scientists. "This," he told them, motioning toward the mansion, "is what we're all working for."

Still, his premature and tragic death is writ large over the intersection of innovation and value. If someone doesn't reassert the essential value of patience and restore a little bit of nobility to the notion of risk, we may all find ourselves, like Bob Swanson, empowered with wondrously powerful search engines that unfortunately have nothing of value to find, especially if you're in the market for something to save your life. ◊

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Serious Play!

Silicon Valley — San Francisco — Los Angeles

Meet Michael Schrage

Fortune columnist, MIT Media Lab Associate and well-known author. His latest book *Serious Play: How the World's Best Companies Simulate to Innovate* is a search for deeper meaning in the world of beta. Meet Schrage and find out how companies such as Disney, Microsoft, Boeing and Daimler-Chrysler use creative improvisation, or serious play, to facilitate the dynamic collaborations that lead to innovation.

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TECHNOLOGY REVIEW

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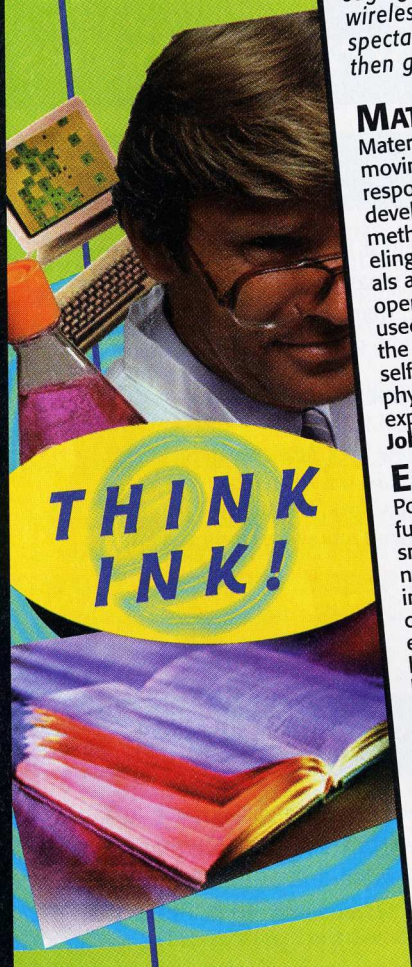
E Ink Corporation, headquartered in Cambridge, Mass., was founded in 1997 to commercialize unique electronic displays. The company has developed a proprietary and award-winning "electronic ink" which enables electronic displays to look and feel like paper. E Ink was named as one of Fortune's twelve Cool Companies of 1998 and has been featured prominently in USAToday, Wall Street Journal, New York Times, Good Morning America, Nature, Scientific American, EE Times, National Public Radio, Economist and others. The first product is a messaging service that enables a nationwide network of large indoor displays to be updated by wireless communication and controlled over the web. Our continued rapid growth has created spectacular career opportunities in these specific areas. Check this list of open positions and then go to our web site to get more details.



Materials Scientist

Materials Scientist desired to be part of a fast moving product development team. Major responsibility will be to work with the team to develop and verify accelerated lifetime testing methods. This will include interpreting and modeling stress tests on displays and display materials and relating these tests to failure modes and operating lifetime. These results will also be used as the basis for making developments in the display system. The successful candidate is a self-starting individual with an MS or greater in physics, chemistry, or chemical engineering and experience in materials development.
Job Code MS/gd/bc

Electrical Engineer

Position will involve all phases of producing functional hardware and low-level firmware for small to medium-scale embedded platforms, novel electronic displays, and communications interfaces. Hardware design skills needed are component selection, system design, schematic entry/capture, and PCB layout. Candidates must have fine pitch surface mount assembly skills to be able to prototype and debug their designs, and should have a good understanding of electronics manufacturing practices in order to generate designs compatible with volume production. Software skills required primarily relate to supporting hardware with routines written in C and Assembler, but possibilities exist for applications development. A significant aspect of the position will be to take first stage prototypes through productization and manufacturing handoff, producing necessary documentation and coordinating agency testing and approval. Ability to work closely with marketing, manufacturing, technology development, and third party personnel is essential. Candidates should have a BSEE and a minimum of 2 years of product engineering experience. **Job Code EE/rc**

Senior Ink Scientist

We have a position for a Physical Chemist/Chemical Engineer or Materials Scientist with leadership experience in successfully delivering materials for innovative commercial products. The qualified candidate will serve as an architect for colloidal materials development for our electronic ink displays. Experience with surface chemistry, dispersion science and materials for electronic devices required. The position requires an MS/Ph.D. degree and 5-10 years of related industrial experience.
Job Code SIS-tr/bc

Senior Ink Physicist

The successful candidate will lead the effort to understand the optical, electrical, and chemical properties of electronic ink devices to assist in rapid materials development. The position will work closely with reliability and materials development teams to develop and test models for device operation and failure mechanisms. Experience in system architecture, physical and chemical properties of complex materials, electro-optical modeling and measurement required. The successful candidate will have an MS/Ph.D. in Materials Science, Physical Chemistry, or Physics with 5-10 years of relevant industrial experience. **Job Code SIP-tr/bc**

Senior Polymer Chemist

Our continuous growth has created a position for a Polymer Chemist responsible for providing leadership in the development of polymeric materials for our electronic ink displays. Experience in materials development for electronic devices, material properties and characterization techniques is required. Experience with microencapsulation chemistry and polymer synthesis desired. Qualified candidates will likely have a Ph.D. degree and 5-10 years of related industrial experience. **Job Code SPC-tr/bc**

Scientist/Engineer

We are looking for creative problem solvers to join our cross-disciplinary team working on rapid development of innovative materials. Experience with polymeric materials and characterization, device physics and performance required. BS/MS and 3-5 years industrial experience required.
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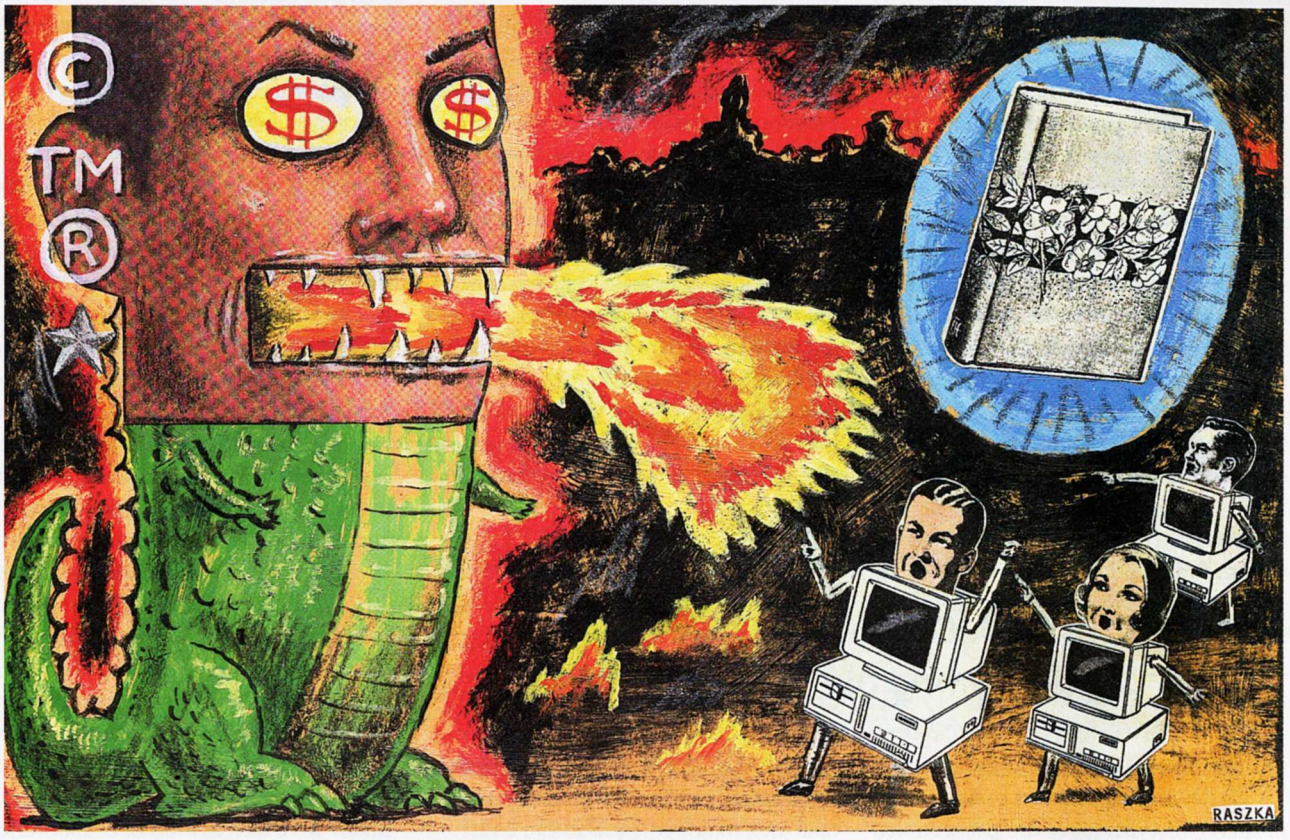

BRIAN RASZKA

VIEWPOINT | BY HENRY JENKINS

IP WATCH

Digital Land Grab

Media corporations are stealing our cultural heritage. Can we take it back?

Between 1869 and 1930, some 200 writers imitated, revised or parodied Lewis Carroll's *Alice in Wonderland.* Some sent Carroll's plucky protagonist into other imaginary lands; others sent different protagonists to encounter the Mad Hatter or the Cheshire Cat. Some promoted conservative agendas, others advocated feminism or socialism. Among Carroll's imitators were literary figures such as Christina Rossetti, Frances Hodgson Burnett and E. Nesbit. Literary critic Carolyn Sigler argues that Alice parodies contributed considerably to Carroll's subsequent reputation. Today, after Shakespeare's work and the Bible, Lewis Carroll's writings are the most often cited in the English-speaking world.

Now try a thought experiment. Imagine that the Wonderland stories were first appearing in 2000 as products of Disney or Viacom, and Rossetti, Burnett and Nesbit were publishing their parodies on the Internet. How long would it be before they were shut down by "cease-and-desist" letters? How many people would download "A New Alice in the Old Wonderland" before a studio flack asserted Disney's exclusive control over Humpty Dumpty™, The Cheshire Cat™ or The Red Queen™?

Rossetti's descendants, now called "fans," borrow characters, situations and themes from pre-existing works (more often television series than novels) and use them as resources for their own stories. Sometimes, such stories offer ideological critiques. Other times, fans recenter the plots around secondary characters or simply provide back story. These modern-day "scribblers" are housewives, secretaries, librarians, students, average citizens; their parodies are labors of love, paying public tribute to popular narratives that capture their imagination.

These fans are also shock troops in a struggle that will define the digital age. On the one hand, the past several decades have seen the introduction of new media technologies (from the VCR to MP3) that empower consumers to archive, annotate,

appropriate and recirculate cultural materials. On the other, the emergence of new economic and legal structures makes tight control over intellectual property the basis for the cross-media exploitation of "branded" materials. We can already see bloody skirmishes over intellectual property as these two trends collide. Not long ago, Fox's lawyers took down dozens of "Buffy the Vampire Slayer" fan sites, and nobody even blinked because such saber rattling has become a regular occurrence.

A year or so ago, J. Michael Straczynski, executive producer of the cult television series "Babylon 5," was speaking to the students in my science fiction class at MIT. One student asked him what he thought about "fans," and after a pause, he replied, "You mean, copyright infringers." The remark was met with nervous laughter and mutual misunderstanding.

So far, most discussions of intellectual property in cyberspace are preoccupied with calming corporate anxieties about controlling the flow of images and information. Technologists have touted new automated enforcement mechanisms that allow owners to ferret out infringements, and digital watermarks for tracing the precise origins of appropriated images. Yet we rarely ask whether such tight regulation of intellectual property is in the public interest. Who speaks for the fans? No one.

That doesn't mean they don't have a case. Indeed, there's much to be said on the scribblers' behalf. Fan critics might be covered by the same "fair use" protections that enable journalists or academics to critically assess media content, or by recent Supreme Court decisions broadening the definition of parody to include sampling. Fans don't profit from their borrowings, and they clearly mark their sites as unofficial to avoid consumer confusion. Fan sites don't diminish market value, often actively organizing letter-writing campaigns to keep floundering programs on the networks.

Sadly, none of this matters. If you are a housewife in Nebraska and you receive a letter from Viacom's attorneys telling you to remove your Web site or they will take away your house and your kid's college fund, you don't think twice about your alternatives. You fold.

As a result, although cease-and-desist orders are routine corporate practice, not a single case involving fan fiction has ever reached the courts. No civil-liberties organization has stepped forward to offer pro bono representation. Presumably, the right to free expression doesn't extend to the right to participate in your culture. As currently understood, the First Amendment protects media producers, but not media consumers. Copyright and trademarks are legal "rights" granted to property owners, while fair use is a "defense" which can only be asserted and adjudicated in response to infringement charges. And most of the people being caught in these battles lack the financial resources to take on a major corporation in court.

Media companies are expanding their legal control over intellectual property, strip-mining our culture in the process.

Disney, Fox and Viacom understand what's at stake here. The proliferating media mergers attest to their recognition that media convergence transforms intellectual property into solid gold. Viacom calls a television series like "Star Trek" a franchise that can generate a seemingly infinite number of derivative products and revenue streams in many media channels. What they can't produce and market directly, they license to another company.

Preparing for this new era, media companies are expanding their legal control over intellectual property as far and as wide as possible, strip-mining our culture in the process. They have made inventive uses of trademark law to secure exclusive rights to everything from Spock's pointy ears to Superman's cape, pushed policies that erode the remaining protections for fair use, and lobbied for an expansion of the duration of their copyright protection and thus prevented works from falling into the public domain until they've been drained of value. In the end, we all suffer a diminished right to quote and critique core cultural materials. Imagine what our holiday season would look like if Clement Moore had trademarked Santa Claus!

For most of human history, the storyteller was the inheritor and protector of a shared cultural tradition. Homer took plots, characters, stories, well known to his audiences, and retold them in particularly vivid terms; the basic building blocks of his craft (plots, epithets, metaphors) were passed from one generation to another. The great works of the western tradition were polished like stones in a brook as they were handed off from bard to bard. This process of circulation and retelling improved the fit between story and culture, making these stories central to the way a people thought of themselves. King Arthur, for example, first surfaces as a passing reference in early chronicles and only over the course of several centuries of elaboration becomes complex enough to serve as the basis for *Le Morte D'Arthur*.

Contemporary Web culture is the traditional folk process working at lightning speed on a global scale. The difference is that our core myths now belong to corporations, rather than the folk.

And that kind of exclusive ownership cuts directly against the grain of the technology in question. From the start, computers were seen as tools of collaboration, designed to facilitate brainstorming and data sharing. If one follows the flow of ideas on a Web forum for more than a few posts, it becomes harder and harder to separate one person's intellectual property from another's. We quote freely, incorporating the original message into our own. When Netizens discuss television, we quote equally freely, pulling chunks of aired material into our posts, and adding our own speculations. Other people respond, add more material, and pretty soon the series as viewed by list participants differs radically from the series as aired. In other words, webbers approach television content as "shareware."

Still, what one originates, the law insists, one should have the right to control and profit from. The legal fiction is that no one is harmed by this land grab on the cultural commons. Tight control over intellectual property isn't ultimately a question of author's rights, because without much discussion, control has shifted from individual artists to media corporations—authors now have little say over what happens to their creations. The

corporate attorneys rule.

If trademarks are used too broadly and without a history of legal enforcement, companies will lose exclusive claims to them—so Coca-Cola sends out spies to make sure nobody gets served a Pepsi when they order a Coke, Xerox insists that we call a photocopy a photocopy and Fox scans the Web to make sure nobody puts an "X-Files" logo on an unauthorized homepage. Attacking media consumers damages relationships vital to the future of their cultural franchises, but corporations see little choice, since turning a blind eye could pave the way for competitors to exploit valuable properties.

Copyright law was originally understood as a balance between the need to provide incentives to authors and the need to ensure the speedy circulation and absorption of new ideas. Contemporary corporate culture has fundamentally shifted that balance, placing all the muscle on one side of the equation. Media companies certainly have the right to profit from their financial investments, but what about the "investments"—emotional, spiritual, intellectual—we consumers have made in our own culture?

Through its "associates" program, the online book dealer Amazon.com encourages amateur critics to build book-oriented Web sites. If they link back to Amazon's homepage, they will get profit points from every sale made to consumers who follow that link. Amazon has discovered that revitalizing a grassroots book culture increases public demand for books. Perhaps media producers should follow Amazon's example and find ways to transform media consumers from "copyright infringers" into niche marketers, active collaborators in the production of value from cultural materials.

Intellectual property law didn't matter much as long as amateur culture was transmitted through subterranean channels, under the corporate radar, but the Web brought it into view by providing a public arena for grassroots storytelling. Suddenly, fan fiction is perceived as a direct threat to the media conglomerates.

One can, of course, imagine that fans should create original works with no relationship to previously circulating materials, but that would contradict everything we know about human creativity and storytelling. In this new global culture, the most powerful materials will be those that command worldwide recognition, and for the foreseeable future, those materials will originate within the mass media.

For the past century, mass media have displaced traditional folk practices and replaced them with licensed products. When we recount our fantasies, they often involve media celebrities or fictional characters. When we speak with our friends, sitcom catchphrases and advertising jingles roll off our tongues. If we are going to tell stories that reflect our cultural experiences, they will borrow heavily from the material the media companies so aggressively marketed to us. Let's face it—media culture is our culture and, as such, has become an important public resource, the reservoir out of which all future creativity will arise. Given this situation, shouldn't we be concerned about the corporations that keep "infringing" on our cultural wellspring? TR

Join Henry Jenkins and TR *readers to discuss IP at www.techreview.com/forums.*

MIXED MEDIA

Flashing the Web

An elegant animation technique is sowing delight—and confusion

A CIRCLE. A STACK OF straight lines. A curved line. A jet-black background. These cryptic geometrical runes are the opening screen at Willing-to-Try.com, an enchanting Web site that showcases a growing cadre of sites using interactive animation to guide users and present complex information.

Select the lines, for example, and you find that they can represent trees, mirrors or rain. Click on trees and a wave of your mouse controls a bird flying through the branches, collecting letters to form words. Grab all the letters in the right order—to spell "elephant," say—and a drawing of an elephant appears, complete with a trumpeting trunk and thundering hooves.

Willing-to-Try.com capitalizes on a technology called Shockwave, developed by Macromedia. Shockwave—along with its even more popular cousin Flash—offers a more efficient way to present visual information. Flash uses "vector graphics" to define images with mathematical descriptions of shapes rather than with pixel-by-pixel maps. That makes for smaller files and quicker downloads, even on slow, dial-up modems. (It does help to have a fast computer, though, to crunch those equations.)

According to International Data Corp., about 88 percent of all Web users have computers equipped with the free software needed to view Flash animation. Shockwave is available to 52 percent of the Web population. Both Flash and Shockwave are moving onto new platforms, such as TV set-top boxes, handheld computers and wireless telephones.

The technology is not without skeptics. Jakob Nielsen, user advocate and principal of the Nielsen Norman Group, dismisses Flash as "a gimmick." First of all, Nielsen says, millions of Web users still don't have Flash-viewing capability. What's worse, Flash disables many Web conventions: the browser's "Back" button, for instance, doesn't work

FLASHY SITES:

Animation Action

Ford Motor (ford.com) Configure your own car and see what it will look like and cost.

Volkswagen New Beetle (turbonium.com) Jazzy, high-energy interface.

IKEA (ikea.com) Interactive instructions for building bookcases.

ESPN (ESPN.com) Animated diagrams of football and basketball plays.

Willing to Try (willing-to-try.com) Animated interface for elegant storytelling.

WDDG (wddg.com) Cool animations and experiments.

Shockwave (shockwave.com) Games, cartoons, music, greetings, creativity.

Macromedia Flash Gallery (macromedia.com/software/flash/gallery/collection/) Company directory of high-profile Flash sites.

MUSIC

Hey, Mr. MP3 Man

Some 35 years after becoming one of the first musicians to meld traditional folk music with rock and roll, Roger McGuinn is still pioneering the folk/tech connection—online. The founder, lead singer and lead guitarist of the legendary rock group the Byrds, has become one of the most recognizable names on MP3.com. His page on the site (artists.mp3s.com/artists/11/roger_mcguinn.html) offers free downloads of nearly a dozen of his recent solo recordings in the MP3 music-compression format that is transforming how audio recordings are distributed. McGuinn offers renditions of old English ballads (like "John Riley"), sea chanteys (like "The Bonny Ship the Diamond"), blues (like "James Alley Blues") and gospel (like "Mighty Day")—all with his infectious vocals and trademark jangly sound of the 12-string guitar and banjo.

"It's very satisfying to get my music out so quickly and easily," notes the 57-year-old recording veteran, who satirized having to "sell your soul to the company who are waiting there to sell plasticware" in his 1960s hit, "So You Want to Be a Rock & Roll Star." The Internet has been receptive to McGuinn. "It's a good thing that a folk song can be in the top 10 of MP3.com," he says. Since the Byrds' heyday, he adds, "the music business has grown to unbelievable proportions." And its hold over pop music still impinges on the new abundance economy of digital downloads. McGuinn explains: "I had a problem last month trying to use 'Mr. Spaceman' on MP3.com. The publisher denied permission, even though

COURTESY OF ROGER MCGUINN

Ex-Byrd McGuinn feeds folk songs to the Net.

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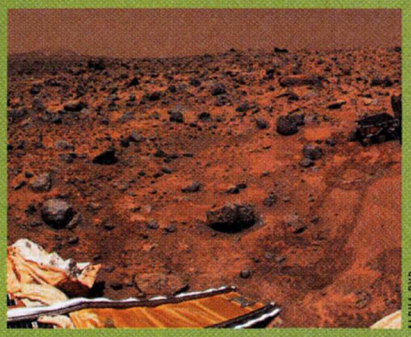

ALPHA DVD

The DVD has landed. Cruise, anyone?

This documentary and planet atlas shows how DVDs and the Web can work as a team. The DVD features simulated flights over Mars based on NASA satellite data, with multiple-camera-angle video. What's best, though, is that the gigabyte-capacity DVD interacts seamlessly with low-bandwidth Web content at the companion site (www.marsdvd.com). In addition to providing updates on Mars exploration (including the lastest on the recent failed landings of two Mars probes), the site also offers packets of screensaver pictures of the red planet. These images won't be sent across the Internet, however, because downloading would take hours. Instead, you pay a fee online and the site sends out a signal that unlocks the images, which are already on the disc.

—Tom Hollon

on Flash-enabled pages.

Moreover, creating truly useful Flash content takes a lot more work and a lot more research than garden variety HTML. Jared Spool, founder of User Interface Engineering in North Andover, Mass., reckons that one minute of animation takes 10 to 30 hours to develop.

Done right, though, Flash animations remind us that the Web can do much more than display words in a row. Willing to Try uses Shockwave to build a charmingly interactive teaching toy. IKEA furniture stores employ Flash to show how to assemble bookshelves—the animated visual guide sure beats those confusing "insert tab A into slot B" printed instructions. ESPN.com uses Flash to diagram pro football and basketball plays. Watching the little symbols dart around the screen is a long way from Xs and Os scratched on the coach's blackboard. And even the skeptical Spool concedes that the best Flash sites are "communicating content in a way that would be very difficult to do otherwise."

—Fredric Paul

I wrote the entire song." (One advantage of folk songs: They are in the public domain.)

McGuinn began putting his folk recordings online five years ago on one of the first home pages by a celebrity on the Web: Roger McGuinn's Folk Den. "I decided to record a traditional song each month in order to preserve them," he recalls. At first the tunes were available from his site (metalab.unc.edu/jimmy/folkden/songs.html) in the bulkier WAV file format, but it took MP3 and its compact files to make his Net music more accessible. MP3 music files are "ten times smaller than WAV, and [the fidelity is] almost as good," he says. For those who see irony in the use of the latest technology to preserve folk traditions, McGuinn points out that much of what he is recording now owes its very existence to a technical breakthrough of the early 20th century: mobile sound recording. "Many songs had been field recordings, captured by folklorists John and Alan Lomax," he observes.

Though McGuinn is convinced that "the Internet will be the future of music distribution," his music is not about to disappear from plastic- and aluminumware. MP3.com is selling three different CD compilations of McGuinn's downloads. In February, Sony's Columbia Legacy series rounded out the Byrds CD catalog with newly remastered versions of three out-of-print albums, as well as a previously unreleased live recording: "The Byrds at the Fillmore—February 1969." But it's the online distribution that has McGuinn floating eight miles high: "I've never had such artistic freedom," he says.

—Steve Ditlea

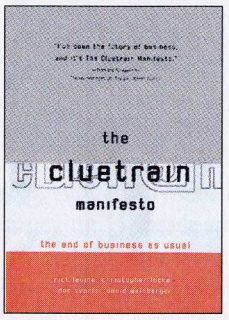
PAGES | BY WADE ROUSH

Manifestly Clueless

THE CLUETRAIN MANIFESTO: THE END OF BUSINESS AS USUAL
By Rick Levine, Christopher Locke, Doc Searle and David Weinberger
Perseus Books, 224 pp., $23

The clue train stopped there four times a day for ten years and they never took delivery.
—Veteran of a firm now free-falling from the Fortune 500

THE *CLUETRAIN MANIFESTO* IS NOT A business book, although that is probably where puzzled booksellers will shelve it. The original Manifesto surfaced in 1999 as a Web site dedicated to the proposition that "markets are conversations." In 95 bluntly worded theses (a nod to Martin Luther), the site ridicules conventional wisdom about marketing and corporate management. "Companies that speak in the language of the pitch, the dog-and-pony show, are no longer speaking to anyone," the Manifesto proclaims. "Most marketing programs are based on fear that the market might see what's really going on inside the company." Outmoded command-and-control management, the argument says, derives from "an overall culture of paranoia." Only by recognizing that information cannot be controlled, that the Web is a tool for community-building rather than broadcasting or advertising, and that customers want to be spoken to in a human voice can companies hope to stay relevant in the new economy, the Manifesto warns.



Bold and irreverent to the point of being smart-alecky, the Manifesto makes a fun, thought-provoking read. It helped me to recognize that, in my day job as the editor of an industry Web site, my role is not just to serve up prepared content but also to fuel conversation with and between readers. I also felt compelled to examine my own writing style for corporatespeak and ivory-towerism. Thousands of other Netizens have become signatories, and the manifesto's authors—a quartet of journalists and marketing consultants—have become gurus of the Web economy.

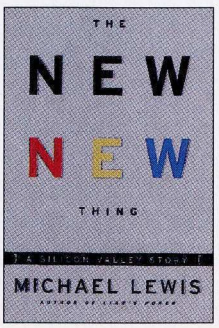
The four deserve kudos for highlighting how the Internet is changing the balance of knowledge and power in the marketplace, and how intranets are doing the same within the workplace. Their effort to save corporations from their own fear of these facts is also valiant. The truth is, though, that the Manifesto's 95 theses boil down to a handful of ideas; the rest is attitude. And while this gonzo voice produces a frisson in limited doses, it becomes suffocatingly smug at book length. Isn't this what the Manifesto warns companies against?

My advice: Skip the book. Go look at the Cluetrain Web site (www.cluetrain.com), read the theses twice, then come back in a week or two and read them again. Then, to keep yourself from taking it all too seriously, go see the wickedly funny parody site, www.gluetrain.com. Thesis No. 17: "If you use lots of really big words like 'metaphysical,' you can stretch four or five ideas into 95 theses."

Creative Destruction

THE NEW NEW THING: A SILICON VALLEY STORY
By Michael Lewis
W.W. Norton, 269 pp., $25.95

JIM CLARK IS PERPETUALLY DISSATISfied. In most people this trait is an affliction, but in people like Clark and other prominent Silicon Valley innovators, it's a strength—at least from an economic point of view. What Michael Lewis calls "the greatest legal creation of wealth in the history of the planet" has been powered by engineers convinced that something in the world needs fixing.

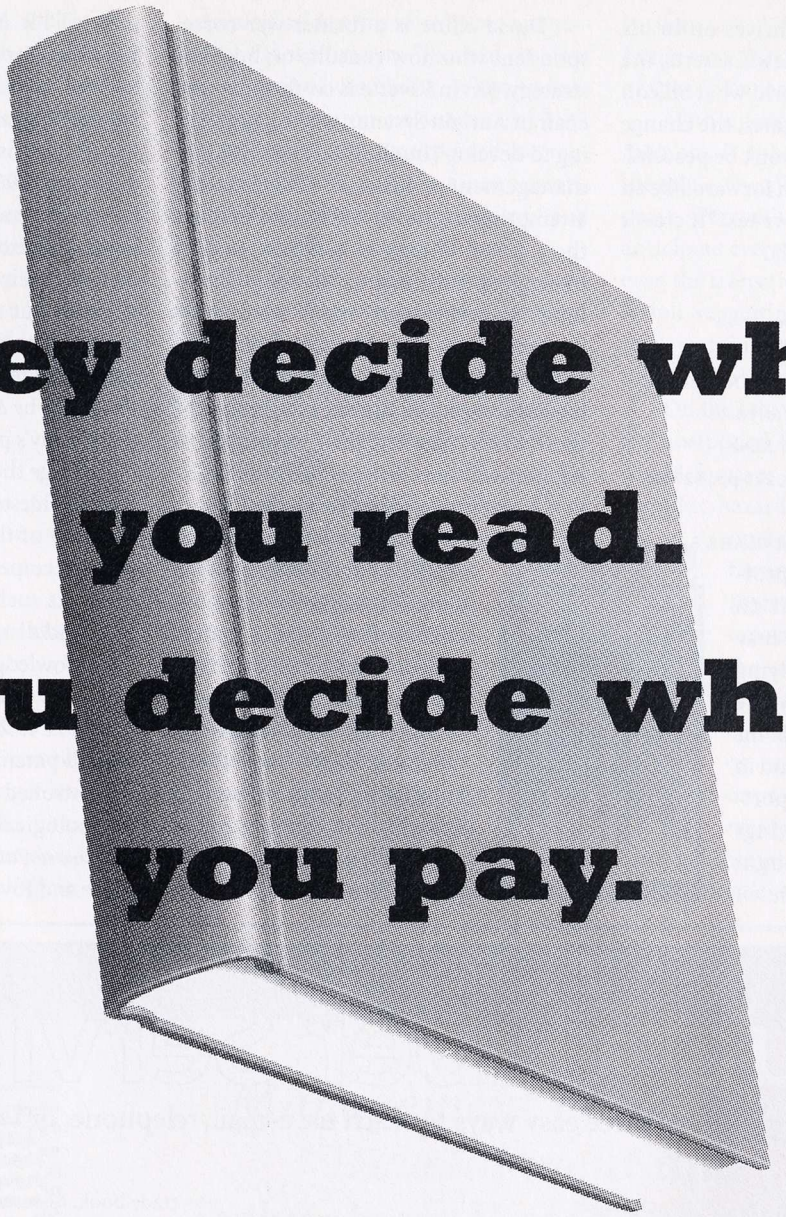


Lewis went to Silicon Valley to understand what Austrian economist Joseph Schumpeter would have labeled the "creative destruction" of the old economy by the new. It was natural that he should gravitate to Clark, whose own lust for change led him to found three of the Valley's heaviest-hitting companies: Silicon Graphics, Netscape and Healtheon.

Lewis is a first-rate storyteller, and no one in Silicon Valley has lived as many stories as Clark. The former mathematician's dissatisfaction with his life as a Stanford professor in the early 1980s led him to build his famous Geometry Engine chip, which became the cornerstone of Silicon Graphics. Clark's contempt for the executives who took control of the firm led him into a rival project to create interactive television. That technology turned out to be impractical, but Clark's interest in interactive media led to the founding of Netscape. Once Microsoft launched a counterattack and Netscape's glitter dulled, Clark was on to Healtheon, which aimed to eliminate paperwork in the health-care industry by mediating every transaction between doctors, patients, hospitals and insurers. When Healtheon struck it rich, Clark once again lost interest and dreamed up myCFO, an Internet "money butler" where the super-rich can pool their billions and buy world domination at a quantity discount.

In his spare time, Clark prodded the Justice Department to sue Microsoft for antitrust violations and built *Hyperion,* the world's largest computerized sailboat. Lewis accompanied Clark on helicopter rides, sailing trips and other hyperkinetic adventures, and saw firsthand that the multibillionaire achieves contentment only when all hell is breaking loose. On *Hyperion*'s maiden crossing of the Atlantic, for example, Clark got interested only when the computer erroneously disabled the engine, a halyard snapped or the sail began to rip in half. "Now that his boat was falling apart, Clark actually appeared to be happy," writes Lewis.

Lewis argues that Clark is to Silicon Valley as Silicon Valley is to America: a great disruptive force. The Internet is bringing to the U.S. economy the same kind of chaos and



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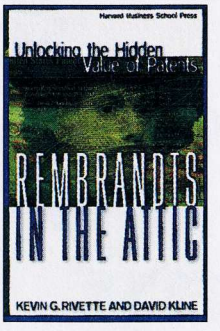
uncertainty that Clark thrives on in his personal life. And if, as Lewis asserts, the United States is to the world what Silicon Valley is to the United States, the change won't stop here—and it won't be peaceful. "Progress does not march forward like an army on parade," Lewis writes. "It crawls on its belly like a guerrilla."

IP Cleanup

REMBRANDTS IN THE ATTIC: UNLOCKING THE HIDDEN VALUE OF PATENTS
By Kevin G. Rivette and David Kline
Harvard Business School Press, 220 pp., $27.50

PERHAPS YOU LACK JIM CLARK'S KNACK for coming up with profitable new ideas. Not to worry—your company may have plenty of old ones lying around. According to the authors of *Rembrandts in the Attic*, it pays to root around in your company's patent portfolio and dust off drawings and formulas you thought you'd never look at again.



David Kline is a former war correspondent who now consults on business strategy. Kevin Rivette is co-founder and chair of Aurigin Systems, a company seeking to develop "intellectual property (IP) management solutions." The two are attempting to convince CEOs to manage their firms' IP just as carefully as they manage operations and finance. Surprisingly, it seems that many companies underestimate the worth of their own patent portfolios. And in an era when successful companies are set apart more by their ideas than by their resources or equipment, that can be a costly oversight.

A patent needn't be turned into a commercial product in order for it to pay off, Kline and Rivette advise. Dow Chemical, for example, once suffered from patent schizophrenia, with each division asserting its own patents in different ways. But after an "IP audit" in the early 1990s, Dow began to coordinate the licensing and commercialization of the firm's 29,000 patents *(see "In Search of Innovation," TR November/December 1999)*. The firm immediately saved $50 million in taxes and administrative costs by abandoning or donating unneeded patents, and watched licensing revenues grow from $25 million in 1994 to $125 million in 1999.

Other encouraging examples fill the book, and executives looking for ways to exploit their patents will find many options. But much of *Rembrandts in the Attic* is just advertising for "IP landscape maps," "patent citation trees" and other tools used by Aurigin Systems to show how a company's patents overlap, complement or infringe those of competitors. And the authors sidestep the ongoing debate on the morality of the patent system, especially when it comes to the patenting of broad concepts such as Dell's continuous-flow sales and distribution model or of scientific knowledge such as a gene's sequence.

In *Owning the Future (reviewed in* TR, *May/June 1999)*, Seth Shulman argued that today's patent practices boil down to "an uncontrolled stampede to auction off our technological and cultural heritage." *(See "Software Patents Tangle the Web," p. 68.)* Kline and Rivette dismiss this as Luddism.

"The expansion of patentable subject matter into new and ever more abstract realms has always met with resistance," yet scientific discovery and innovation have only intensified, they assert.

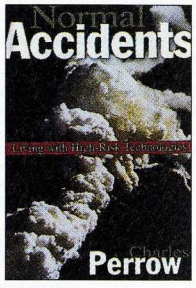
This is a book about maximizing profits, not about morals, and on that level it is a success. But inadvertently, it also opens a window on a disturbing world, one where ideas can be bought and sold like chattel and executives would rather sue each other for patent infringement than think an original thought.

Be Afraid

NORMAL ACCIDENTS: LIVING WITH HIGH-RISK TECHNOLOGIES
By Charles Perrow
Princeton University Press, 451 pp., $19.95

WHEN CHARLES PERROW PUBLISHED *Normal Accidents* in early 1984, the catastrophes at Bhopal and Chernobyl and the crashes of the Challenger and the Exxon *Valdez* were still in the future. Yet Perrow's warnings about the dangers of complexity and tight coupling in large technological systems were borne out perfectly by these disasters. "Normal accident theory" gained credibility. When today's investigators examine disasters, they look for, and often find, unexpected interactions between design flaws, human errors, self-defeating "safety" mechanisms and broken or deluded organizations.

The approach of 2000 provided a good occasion for Perrow to update and expand his groundbreaking book. The new edition, which appeared in paperback in November, gives him not only a well-deserved chance to say "I told you so," but also an opportunity to go on the record with his predictions about the Y2K problem—"that rare potential disaster that we can see coming, can plan for, and can prognosticate about." In Perrow's view, technological breakdowns and social chaos would further vindicate his argument that our critical systems are too highly computerized and too tightly interlinked. An uneventful January 1 would be an indication that our systems aren't as interdependent as we thought or, more likely, that our Y2K preparations paid off. Either way, "Y2K will permit a kind of test of the robustness of societies."



With a peaceful 1/1/00 receding into memory, it appears that we have passed the test. A few glitches have cropped up to prove Perrow's maxim that we can't anticipate everything. In the main, however, the transition has been unexpectedly dull, suggesting that we have taken Perrow's warnings to heart (or that the whole thing was wildly hyped to begin with).

On the other hand, we may have simply postponed the kind of debacle that would force us into a reexamination of complex, hazardous technologies such as nuclear power. In particular, the increasing ubiquity of the Internet, to which every thermostat and sprinkler system in the world may soon be linked, is creating the potential for an epidemic of computer viruses or other disruptions on an unprecedented scale. There will never be another year 2000, but I suspect this won't be the last edition of *Normal Accidents*. TR

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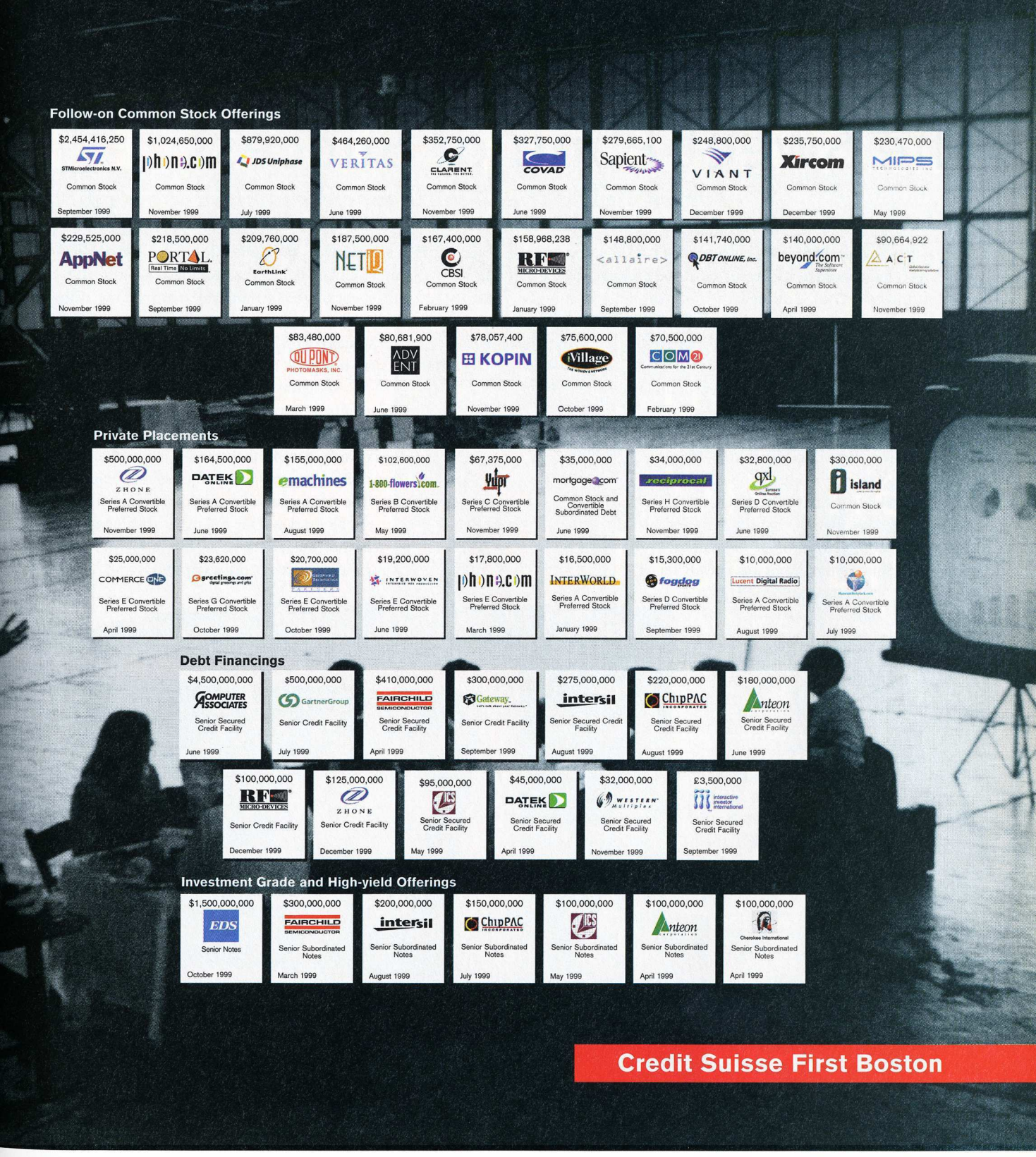

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The Sweet Pong of Success

It was just a trial—until quarters jammed the prototype

In November 1972, Nolan Bushnell and Al Alcorn wheeled a strange apparatus into Andy Capp's Tavern in Sunnyvale, Calif. Bushnell, the founder of a new company called Atari, and Alcorn, Atari's first engineer, set up the cube-like device on a barrel and switched it on. Two dials were set below glowing rectangles on a screen. The instructions read: "1. Insert quarter. 2. Ball will serve automatically. 3. Avoid missing ball for high score." Curious patrons began to follow step one.

Before long, the thing stopped working. Alcorn returned to the bar to check it out. Opening it up, he saw that the side-mounted coin mechanism (from a laundromat) was jammed—brimming with quarters. Pong was already on its way to being the first commercially successful video game.

The sound made by this game was a pong heard around the world, the opening volley in a long, playful exchange between people and computers. The video-game industry started by Pong brought computers out of esoteric data centers and into bars and movie-theater lobbies. The children of the 1970s began to accept computers as fun and accessible—even welcoming them into their homes in the form of the tremendously popular Atari 2600 Video Computer System.

Bushnell had assigned Alcorn to make Pong as a trial project (it would be easier to create than a driving game, for example) and never intended to manufacture it. But as quarters kept pouring in, he reconsidered. Atari started manufacturing upright Pong units. Pong was not only fun, it was cleverly made. For example, because monitors were costly, Pong incorporated a cheaper black-and-white Hitachi television as the display.

A year before creating the Pong prototype, Bushnell had built the very first coin-operated video game, Computer Space, based on a 10-year-old computer game called Spacewar. Perhaps because of its overly complex controls, the game flopped. Even earlier—in 1958—William Higinbotham at the Brookhaven National Laboratory had built a working electronic table-tennis game, using an analog computer. Though the proto-Pong game amused lab visitors for two years, it failed to spur an industry.

Pong was the first to combine the critical elements: a simple interface, amusing play and technology that was cheap and easy to manufacture. A decade after that first coin slot jammed, arcades full of Pong progeny were bringing in $5 billion a year. The video-game industry crash of the mid-1980s shook Atari and the rest of the gaming arena. But by that time, arcade games had introduced an entire generation to playful computing. ◊

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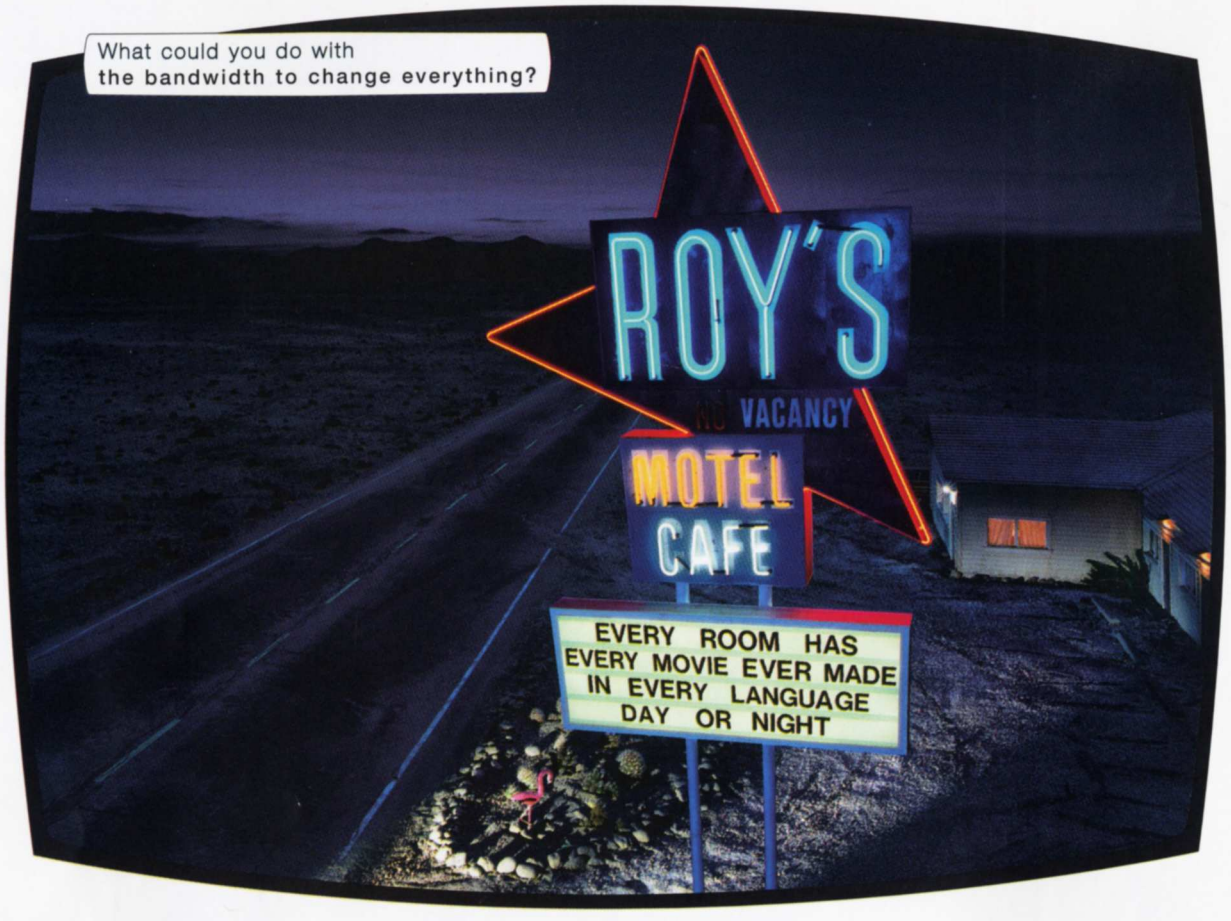

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